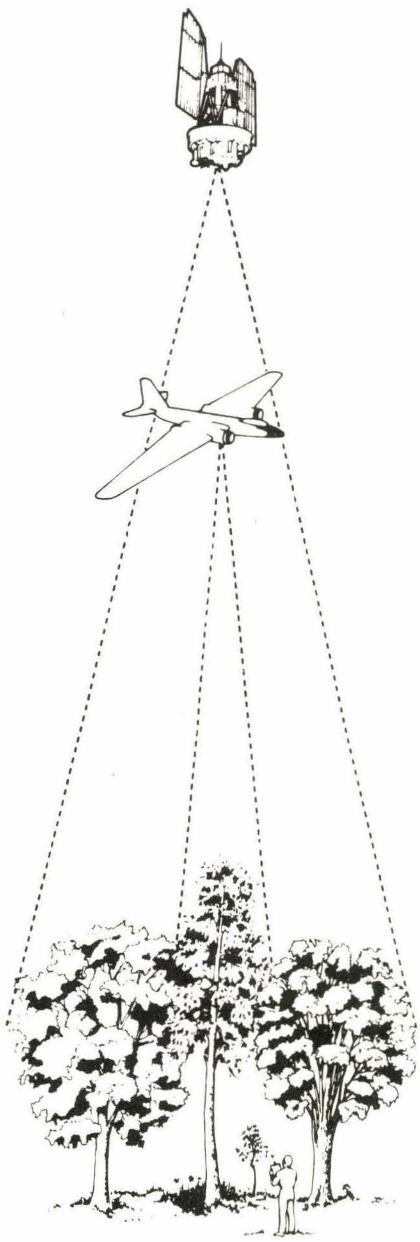
NATIONWIDE FORESTRY APPLICATIONS PROGRAM



TEN-ECOSYSTEM STUDY (TES) SITE VIII,
GRAYS HARBOR COUNTY, WASHINGTON,
FINAL REPORT

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NOTE: In 1976, the Nationwide Forestry Applications Program was expanded from a Regional project by cooperative agreement between the Forest Service, U. S. Department of Agriculture, and the National Aeronautics and Space Administration (NASA). The Program is designed to sponsor research and development on the application of remote sensing analysis techniques to problems arising from the need to inventory, monitor and manage forests and rangelands, including the assessment of impacts on forest stands from insect and disease damage.

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16. Abstract

This final report presents the findings, conclusions, and recommendations obtained from the automatic data processing analysis of Landsat and photographic data acquired over Grays Harbor County, Washington, Site VIII of the Ten-Ecosystem Study (TES). This site was selected to be representative of the Pacific Coast Conifer Ecosystem.

The analysis of the processing results has led to the following conclusions:

a. Level II forest features (softwood, hardwood, clear-cut, and water) can be classified with an overall accuracy of 71.6 percent ± 6.7 percent at the 90-percent confidence level for the particular data and conditions existing at the time of this study.

b. Signatures derived from training fields taken from only 10 percent of the site are not sufficient to adequately classify the site.

c. The Level III softwood age group classification appears reasonable, although no statistical evaluation was performed.

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PREFACE

The Nationwide Forestry Applications Program was established in 1971 at the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, to develop and to demonstrate the use of remote sensing technology for inventorying forestry resources, with particular application to the needs of the Forest Service of the U.S. Department of Agriculture.

During the period of 1971-75, many small and localized feasibility studies plus the technological development of automatic data processing systems and conventional photointerpretation analysis were conducted. The studies were directed primarily toward specific applications within Region VIII of the Forest Service. The need for extending the technology to intermediate-scale and large-scale applications was reflected in the passage of the Forest and Rangeland Renewable Resources Planning Act, Public Law 93-378. In response to some of the requirements of this act, the Ten-Ecosystem Study was initiated to investigate the feasibility for analysis of forest and grassland ecosystems on a national scale using Landsat data.

The Ten-Ecosystem Study is an automatic data processing study using Landsat data, supporting aircraft imagery, and ancillary information for inventorying forests, grasslands, and water by administrative boundaries in 10 categorized ecosystems of the United States. For each specific ecosystem, the analysis success, the problems, and the failures are clearly and objectively identified. Recommendations which are directed toward future large-area inventory analyses in each specific ecosystem are made. And based upon the combined experience gained on each study of the 10 ecosystems, recommendations on the definition and requirements of a preliminary integrated automatic data

processing analysis system to inventory nationwide forest and grassland renewable resources are also offered.

The primary objectives of the Ten-Ecosystem Study are:

a. To investigate the feasibility of using automatic data processing of remotely sensed data to inventory forest, grassland, and inland water areas within administrative boundaries for specific ecosystems of the United States

b. To identify automatic data processing analysis problems related to each site of each ecosystem and recommend solutions

c. To define the requirements for an automatic data processing system to perform a nationwide forest and grassland inventory

These objectives will be addressed in the Ten-Ecosystem Study final report scheduled for completion early in 1979.

This report is the analysis of Site VIII, Grays Harbor County, Washington, which was selected to represent the Pacific Coast Conifer Ecosystem. It is the final of four reports covering the study conducted for Site VIII. This report was prepared by Lockheed Electronics Company, Inc., under Contract NAS 9-15800, Job Order 75-325, Action Document 63-1737-5325-50. Distribution of this report has been approved by the supervisor of the Forestry Applications Section and the manager of the Earth Observations Exploratory Studies Department.

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ACRONYMS

ADP	automatic data processing
ERIPS	Earth Resources Interactive Processing System
Image 100	Interactive Multispectral Image Analysis System, Model 100
JSC	Lyndon B. Johnson Space Center
Landsat	NASA land observatory satellite
NASA	National Aeronautics and Space Administration
NFA	Nationwide Forestry Applications
PCC	percent of correct classification
pixel	picture element
PSU	primary sampling unit
PMIS/DAS	Passive Microwave Image System Data Analysis Station
SSDA	Sequential Similarity Detection Algorithm
SSU	secondary sampling unit
rms	root mean square
TES	Ten-Ecosystem Study
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

1. INTRODUCTION

An account of the work performed on the Ten-Ecosystem Study (TES) site located in Grays Harbor County, Washington, is presented in this report. This site, known as Site VIII, is the eighth of nine sites[1] which were studied in the TES.

The automatic data processing (ADP) portion of the TES consists of a separability study and a simulated inventory study. The separability study is designed to establish the level of classification detail which is possible to achieve using the National Aeronautics and Space Administration (NASA) land observatory satellite (Landsat) data. The simulated inventory study is used to determine how far the classification of features can be extended successfully using limited ground-truth data.

For evaluation, seven Landsat transparencies were studied to determine the best seasons to use in the ADP portion of the TES. Results from the separability study portion of the image processing show Level II training field accuracies to be greater than 90 percent for all features, with the exception of the hardwood class which has a training field accuracy of only 85 percent on September 12, 1974. The accuracies are for training fields only and not for the overall classification, as no statistical evaluation was performed on the separability study results in accordance with the TES procedures (ref. 1). Further differentiation of the softwood class into its age components has been attempted with a Level III separability classification.

Classification results based on the simulated inventory study were evaluated statistically to determine the map classification

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[1] One site encompasses two ecosystems, accounting for only nine sites within the ten ecosystems.

and feature proportion accuracies. For each phase of the work, both man-hours and machine hours are recorded in order to establish guidelines for future project planning.

2. PRELIMINARY SITE ANALYSIS AND FAMILIARIZATION

A summary of objectives, procedures, and results of the preliminary analysis and site familiarization of Site VIII is discussed in this section. A brief description of the area and the cultural history of this TES site is included for more exposure to Grays Harbor County, Washington.

The two tasks, preliminary site analysis and familiarization, were designed (1) to establish the two Landsat dates to be used for computer analysis and (2) to ensure that the site familiarization provides firsthand ground information and background data on geology, soils, climate, and vegetation with respect to forest management practices.

A team, consisting of one member from the Forest Service of the U.S. Department of Agriculture (USDA), one NASA/Lyndon B. Johnson Space Center (JSC) member, and three Lockheed Electronics Company, Inc., employees, visited Site VIII for 1 week from September 19 through 23, 1977. Local staff from the Forest Service at Olympic National Forest was available to accompany the field teams for 2 days. The purpose of the visit to Site VIII was (1) to familiarize the scientist and analysts working on Site VIII with the characteristics and anomalies of this site, (2) to investigate predetermined areas that were to be used as training fields for computer classification and as ground-truth data for evaluation of the final products, and (3) to coordinate with the Forest Service staff and scientists at the Olympic National Forest for pertinent ancillary information and other knowledge useful to the TES.

2.1 OBJECTIVES

Listed below are the objectives of the preliminary site analysis.

a. To select the best Landsat data of those available for processing on the Interactive Multispectral Image Analysis System, Model 100 (Image 100)

b. To provide initial site familiarization (This provides a basis for selecting training fields and identifying anomalous areas to be ground checked.)

c. To provide information on the changes in vegetation characteristics with time

Listed below are the objectives of the site familiarization task.

a. Collecting information on site geology, soils, climate, and vegetation including forest management practices

b. Contacting Forest Service personnel at the site for firsthand information

c. Acquiring firsthand information on prospective training fields by field examination of selected areas

2.2 SITE DESCRIPTION

Site VIII is a 60- by 60-kilometer (37- by 37-mile) area located within Grays Harbor County, Washington, on the Olympic Peninsula (fig. 2-1). Northern portions of the site consist of the Olympic National Forest and the Olympic National Park. The majority of the southern half of the area consists of privately owned timber company lands which show a high degree of forest management and lumbering activity. No large towns are within the study site, although the towns of Hoquiam and Aberdeen are located nearby and several small towns are located throughout the site. Major transportation systems are the Forest Service and county roads, river transportation, and logging railways.

This area was chosen as a TES site because of its diversity of species, recent forest management activity, economic importance, and availability of NASA 1:120 000-scale color-infrared photography.

The coordinates of Site VIII were suggested by scientists and personnel of the Olympic National Forest for use by the Nationwide Forestry Applications (NFA) Program. The coordinates are:

47°40' N., 124°03' W.
47°35' N., 123°15' W.
47°03' N., 123°35' W.
47°08' N., 124°10' W.

2.2.1 CULTURAL HISTORY

The forests of the Pacific Northwest are the greatest single resource of the region; this is particularly true of Grays Harbor County, Washington. The site is about 90-percent forest; the nonforested areas are devoted to agricultural and urban uses. More than 75 percent of the forested area is under private ownership. Private lands are generally the better and more accessible areas; thus, most have been logged at some time in the past and are in some state of regeneration. The Olympic National Forest still contains some old growth forest and is now being carefully logged using modern management practices. The forest dominates the economic base of the area, with most jobs being related to the forest product industries. Large sawmills are located in the town of Aberdeen; however, smaller mills devoted to shake and shingle manufacturing are scattered throughout the site. The economy of the area is stable, neither growing nor diminishing to any great extent.

There are some commercial and sport fishing activities located around Grays Harbor. The community of Ocean Shores represents

the largest local recreation area on the coast. The economy of these activities are minor in comparison to the forest product economy. The recreation industries are, for the most part, intimately associated with the forest and national park lands. Hunting, fishing, climbing, and hiking are activities that attract thousands of visitors per year to the area. The recreation industries offer job opportunities to residents of Quinault and Amanda Park, Washington.

2.2.2 PHYSIOGRAPHY AND TOPOGRAPHY

Three physiographic regions are represented within Site VIII. These are most noticeable as one goes from the southwest to the northeast, changing elevation from sea level to a height of 2200 meters (7216 feet). Within this area are an abundance of water resources, varied climatic conditions, varied geological and soil formations and deposits, and an extensive coverage of vegetation primarily forest land. More details on these topics are covered in subheadings in this section.

The topographic features of Grays Harbor County, Washington, are represented by sea level terrain, rolling hills, and mountain ranges. The northern portion of the site, which is within the Olympic National Forest, has numerous ridges and valleys, the Olympic Mountain region having the highest elevation. Drainage of the area is primarily westward and southward toward the Pacific Ocean. The runoff is carried by the many creeks, intermittent streams, and rivers. Figure 2-2 is a stereogram of the aerial photography reflecting elevation and drainage.

2.2.2.1 Water Resources

Precipitation and good drainage make possible the many rivers, lakes, streams, and ponds which exist throughout Site VIII. The Quinault River, fed by tributaries within the Quinault Indian

Reservation, drains into the Pacific Ocean. Some of the longest rivers within Site VIII are the Humptulips, Hoquiam, Wishkah, Wynoochee, and Satsop. All are navigable by shallow draft vessels, and some are used to transport logs to sawmills in the towns of Aberdeen and Hoquiam. Recent damming of the Wynoochee River created the Wynoochee Reservoir. Two major lakes are found within the site; namely, Quinault Lake and Lake Cushman. Many smaller lakes, ponds, and marshes occur in low-lying areas. All provide habitat for water fowl and acquatic life; the streams abound in salmon, steelhead, and trout.

Within the Pacific Coast Conifer Ecosystem (Site VIII), water resources also help to provide optimum conditions for a variety of vegetation, particularly forests. The Olympic rain forest surrounding Quinault Lake resulted from the optimum conditions of high rainfall and well-drained soils.

2.2.2.2 Geology

Deposits of the northwestern, northeastern, and southwestern quadrants of the site can be described as terrace deposits. These deposits are unconsolidated to partly consolidated fluvial and glaciofluvial sand and gravel with minor amounts of silt and clay. Alluvium, consisting mostly of unconsolidated silt, sand, and gravel with some clay, is found to the west and south of the Olympic National Forest in association with major drainage systems. This low-lying area contains some low-level terrace, marsh, peat, artificial fill, and glacial deposits in local areas.

The southeastern portion of the site contains extensive pockets of Miocene and Pliocene marine sediments. These are brown-gray, coarsely-grained, moderately-consolidated, and crossbedded sandstone, claystone, and shale. Alluvium and glaciofluvial deposits can be found overlying these deposits in the valleys.

The northeastern portion of the site consists mainly of middle and lower Eocene volcanic rocks. These rocks are dark gray, coarse to fine crystalline, strongly-chloritized basalt flows, and breccia. The rocks include some pillow lava, deeply altered palagonite beds, amygdaloidal and vesicular flows, and some local sedimentary rocks. Some manganese ore is found in association with submarine lavas. Additionally, small pockets of metamorphic and intrusive igneous rocks occur in tertiary dikes, sills, and small intrusive bodies within the Olympic National Forest. A thrust fault is present on the extreme northern edge of the site, forming the boundary between the volcanic rocks and sedimentary rocks of the fault. Figure 2-3 illustrates the geology of the area (ref. 2).

The study site and the entire Olympic Peninsula are virtually devoid of economically important minerals. Some garnet and corundum deposits are present in sufficient quantities to warrant mining activities; and a small amount of manganese ore is found in association with pillow lavas, but seldom in sufficient quantities to permit mining. However, numerous sand and gravel quarries are found and dug for use in road construction.

2.2.2.3 Climate

Site VIII has a maritime climate which is cool with heavy winter precipitation as rain and snow and relatively dry summers. The area is influenced by the wind direction, the ocean surface temperatures, the terrain, and the intensity of high and low pressure centers over the northern Pacific Ocean.

Precipitation is heavy throughout the area in the Quinault Ranger District, which is northwest and southeast of Quinault Lake. The average annual rainfall is from 305 centimeters (120 inches) in the lowlands to 508 centimeters (200 inches) on the high ridges.

In the Shelton District, located eastward from Quinault Lake to Lake Cushman, the average annual precipitation rate ranges from 305 centimeters (120 inches) to 560 centimeters (220 inches) in the lower valleys (below 1370 meters or 4493 feet to greater than 635 centimeters or 250 inches in the high mountains). Rainfall varies in response to changes in elevation as well as changes in mean soil temperature.

The temperature range is moderate, with an average January temperature of 3.55° C (38.4° F) and an average July temperature of 17.5° C (63.5° F) at Quinault Lake. Site VIII averages approximately 200 frost-free days per year, and the average date of the last killing frost is April 20 (ref. 3).

2.2.2.4 Soils

According to Andols' "seventh" approximation (ref. 4), soils of Grays Harbor County, Washington, are primarily inceptisols which are defined as soils with weakly differentiated horizons; that is, materials in the soil have been altered or removed but have not accumulated. The soils are usually moist but are dry during the warm season of the year. All the soils of Site VIII support woodlands, grassland, or pasture.

The inceptisols are further defined as andepts or umbrepts. Andepts form in ashy (vitric pyroclastic) materials; they contain low-bulk density and large amounts of amorphous material.

Umbrepts are inceptisols with crystalline clay materials. They have thick, dark-colored surface horizons. The altered subsurface horizons are low in bases and have lost their mineral materials.

Histosols are wet organic (peat and muck) soils found in some low-lying areas. Their classification is based upon the extent of decomposition of plant residues from highly decomposed to nondecomposed.

The Forest Service staff at the Olympic National Forest further defines the soils of the area according to their relative topographical position and in relation to the parent material from which the soils have formed (ref. 5). The soil map with legend in figure 2-4 illustrates the soil classifications used by the Forest Service staff at the Olympic National Forest.

2.2.2.5 Vegetation

Forest land covers more than 90 percent of this study site, and the remaining area is devoted to agriculture and urban land use. More than 75 percent of the forested area has been logged at some time in the past; however, some virgin forest still exists within the Olympic National Forest. Most stands exhibit some stage of second growth.

The major forest species encountered within the site are western hemlock (*Tsuga heterophylia*), western redcedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), red and Sitka alder (*Alnus rutra* and *Alnus sinuata*), and Douglas fir (*Pseudo-tsuga taxiflora*) (ref. 6). Minor amounts of Pacific silver fir (*Abies amubilis*) are found at the higher elevations, above 305 meters (1000 feet); and good stands can occur at elevations up to 1371 meters (4500 feet). The varied conditions of climate and elevation contribute to the diversity of species and their associations.

Three broad categories of tree associations found within Site VIII are spruce/hemlock, hemlock/cedar, and hemlock/Douglas fir. With the exception of recently planted stands, few pure stands were seen during the site familiarization.

Normal ecological succession in clear-cut areas has been disturbed by a variety of forest management practices. Of course, planting after clear-cutting is intended to preclude normal ecological succession. Some management practices can influence the type of regeneration that occurs after clear-cutting. For example, planting of seedlings is more commonplace today. If replanting occurs after clear-cutting, there is a preference to plant Douglas fir because of its economic importance. On the wetter western portions of the site, these plantings come into competition with hemlock from local seed sources. Consequently, by the time the stand is ready for harvest, it may be primarily hemlock as hemlock is more competitive in a moist situation.

Recently, there has been a movement toward clear-cutting small areas, thus leaving the conifer seed sources close enough to the cut to allow the conifers to become readily established without competition from the alder. In the Grays Harbor County area, the alders appear to establish more rapidly in areas that have been burned after harvest. The alder tends to disseminate seed better and to grow more rapidly than the conifer, and the alder also has the ability to sprout from old stumps. However, it is slightly intolerant, a short-lived species, and will eventually be replaced by Douglas fir, hemlock, and cedar stands where these seed trees are within the proximity of the clear-cut.

The hardwoods in the area such as the alder, bigleaf maple, and vine maple are primarily restricted to stream banks, favoring the more moist conditions; or they are found as pioneer species after a clear-cut. Some bigleaf maple is found on the flatter alluvial soils located near the larger rivers. Some scattered hardwoods, primarily red alder, are found within hemlock, cedar, or Douglas fir stands when these stands are in a climax condition. As some of these trees succumb to disease, the resulting clear areas

receive sufficient sunlight to allow red alder to grow. These trees rarely exceed 15.24 meters (50 feet) in height. Red alder may be harvested as a commercial crop and used in the manufacture of cabinets and furniture. No commercial cuttings of the bigleaf maple were evident in Site VIII.

The major understory species are restricted to mosses, ferns, salmonberry, and salal. Naturally, mosses and ferns are found more frequently in the wetter regions. In some areas, mosses and ferns form a mat up to 0.61 meter (2 feet) thick under a climax condition stand. The pole-sized second-growth hemlock stands are usually so dense that understory species are restricted to a shallow blanket of moss. Salal and salmonberry are better suited to the dryer areas and are most often found in association with stands of Douglas fir. Bogs are occupied by mosses, liverworts, and ferns.

Figures 2-5 through 2-11 show examples of the vegetative types found within Site VIII.

2.2.2.6 Wildlife

The wildlife of the area is closely associated with the forest habitat and consists of deer, elk, black bear, squirrel, rabbit, and other rodents. The increased logging activity has increased the amount of preferred habitat for both elk and deer.

2.3 DATA UTILIZATION

Selected data were evaluated according to procedures established in TES procedures (ref. 1). The data sets used in Phase I (Site Familiarization, Task I.5) and Phase II (Data Compilation, Task II.1) are described in this subsection.

2.3.1 AERIAL PHOTOGRAPHIC DATA

The aerial photographs, which were interpreted for data selection, were from NASA Mission 73-074A (flight of May 11, 1973). The photographic frames were 1193-1205, 1206-1218, and 1219-1231; the film was color infrared (Kodak 2443) on 23- by 23-centimeter (9- by 9-inch) transparencies and contact prints at a scale of 1:120 000. Figure 2-12 is an example of an aerial photograph.

The aerial photographs were used for the following purposes.

a. To make land cover classification overlays of the site

b. To familiarize the personnel working on the site with the physiographic and vegetative features of the site

c. To select training fields for investigation

d. To train the computer operator

e. To serve as a recent map to locate training fields on the ground

Manual photointerpretation of a portion of Site VIII was done with the color-infrared photographs using an Old-Delft scanning stereoscope. A total of three stereoscopic models was used to complete the task. The frames used in the interpretation process were 1210, 1211, 1228, 1229, 1207, and 1208; of these frames, 1210 and 1208 were interpreted. The area was cloud free and virtually devoid of haze when the photographs were taken and the quality of the aerial photography was good.

During the manual photointerpretation phase of the work, a Level II interpretation was used. This intense interpretation (1) allows the investigators to become more familiar with the site, (2) enables the field teams to use the interpretations as an updated map from which training fields can be easily located

on the ground, and (3) serves as ground-truth data for the Level III ADP classification (see section 2.4).

Several anomalies were noted during the photointerpretation phase and are outlined below.

a. Areas outside the boundaries of the Olympic National Forest showed spectral signatures considerably different from those within the national forest. It was hypothesized that these areas, which are privately owned forest lands, had been subjected to somewhat different management practices than those used for the national forest. The national forest consists primarily of forested lands which, until recently, could not feasibly be harvested because of steep terrain and general inaccessibility; thus, this area has had minimal disturbance. Consequently, the undisturbed forest lands plus the noticeable increase in the amount of shadow associated with the steeper terrain may have contributed to the differences in the signatures.

b. Areas thought to be hardwoods from their spectral signatures were far more prominent on the privately owned forest lands. Areas previously clear-cut and not regenerated showed very bright signatures, indicating possible hardwood regeneration. These areas later proved to be young softwood stands, and some confusion could be expected in the ADP portion of the study as the photography was taken in early May 1973. On this date, the young conifers were exhibiting the new growth at the ends of the branches, and this new growth may be the reason for the spectral confusion between hardwoods and young conifers on the aerial photographs.

The 10-percent area used for the simulated inventory study was selected during the manual photointerpretation phase also. This was done so that the area would contain a representative sample

of all vegetative types within the site. Ground-truth data were limited to the photointerpretation of the 1:120 000-scale photographs as the 10-percent area was not to be visited during the field trip.

2.3.2 CARTOGRAPHIC DATA

Two different types of maps proved useful. The Olympic National Forest maps, which show all of the Forest Service roads, were used for navigation between sample sites. The U.S. Geological Survey (USGS) 1:250 000-scale maps proved useful for a general overview of the area and for planning purposes.

2.3.3 ANCILLARY DATA

Some research of the site was completed prior to the site visit so that the site scientist would be familiar with the area upon arrival. This research was done on a very general level in the disciplines of soils, climatology, geology, vegetation, and hydrology which were discussed in subsection 2.2.2.

2.3.4 LANDSAT IMAGERY

Seven frames of Landsat imagery were initially ordered in the form of 23- by 23-centimeter (9- by 9-inch) transparencies. Two of these frames were selected to be used in the ADP processing portion of the task. The following is a list of the frame numbers, the dates of Landsat frames, and the reason why they were or were not chosen.

Frame number	Date	Elimination or acceptance	Reason
1097-18380	10/28/72	Rejected	80 percent cloud cover and/or haze
1133-18381	12/03/72	Rejected	60 percent cloud cover and/or haze
1169-18375	01/08/73	Rejected	No cloud cover; some snow and ground fog
1187-18380	01/26/73	Accepted	No cloud cover
1241-18383	03/21/73	Rejected	25-percent cloud cover
1781-18272	09/12/74	Accepted	No cloud cover
1817-18263	10/18/74	Accepted	No cloud cover

The process by which the best two dates of the three accepted frames were chosen follows. High-altitude color-infrared photographs (scale 1:120 000) and Landsat color composites over the study site were interpreted using procedures described in reference 1. The photointerpretation of one frame of the color-infrared photographs was compared with the interpretation of the corresponding area on the three Landsat color composites (scale 1:1 000 000). Both the Landsat composites and the 1:120 000-scale photographs were interpreted based upon tonal properties and using procedures similar to those defined by the Forest Service found in the Photointerpretation Guide for Forest Resource Inventories (ref. 7) and Forester's Guide to Aerial Photo Interpretation (ref. 8). The aerial photographs were viewed stereoscopically and magnified four times to the scale of 1:30 000; the Landsat scenes were enlarged to a scale of 1:250 000. Assuming the photointerpretation to be 100-percent accurate, the overall map accuracy or percent of correct classification (PCC) was calculated for softwood, hardwood, grassland,

and other. The following list represents the PCC's from the comparison of the Landsat scenes versus the 1:120 000-scale aerial photographic interpretations.

Date	Image identification	Overall PCC	Remarks
01/26/73	1187-18380	59.0	No cloud cover
09/12/74	1781-18272	59.5	No cloud cover
10/18/74	1817-18263	56.5	No cloud cover

The results of the above test indicated that the January and September dates had the best cloud-free scenes available for classification. The computer tapes of these two dates were ordered and provided good quality data for ADP analysis. Figure 2-13 shows the September 12, 1974, Landsat image.

2.4 HIERARCHY OF FEATURES

The basic concept was to interpret aerial photographs of the site to determine all the recognizable classes and to use this classification hierarchy for comparison with the classes identified from the Landsat imagery.

For the manual photointerpretation, a classification scheme designed particularly for the Pacific Conifer Coast Ecosystem was used and is listed below.

1.	Softwood	5.	Water
2.	Hardwood	6.	Urban
3.	Clear-cut	7.	Agriculture
4.	Pasture		7.1 Agriculture, exposed soil

The categories of classification which are necessary for ADP are:

Level I	Level II
Forest	Hardwood
	Softwood
	Clear-cut
Nonforest	Water
	Other

The clear-cut category was used rather than grassland as specified in the TES procedure (ref. 1) because there was no significant amount of grass within Site VIII and because a significant amount of clear-cutting had occurred in the area, therefore the clear-cut category was more accurate for this site. (The clear-cut areas were in various stages of reforestation.)

Although the Levels I and II hierarchy is all that is required by the TES Site VIII report (ref. 9), a Level III classification based upon the age of the conifers seemed to offer the possibility of reasonable success. The spectral reflectance of the older trees (virgin growth) in the national forest was somewhat different from that of the younger conifers; and this indicated a basis for a computer Level III classification.

<u>Level III</u>

Softwood 1
Softwood 2
Softwood 3
Hardwood (alder)
Clear-cut
Improved pasture
Water

The category of softwood 1 includes all softwoods greater than 95 years of age, irrespective of species. This category is generally the old growth timber and more prevalent in the Olympic National Forest and the Olympic National Park. The softwood 2 category consists of regenerated softwood younger than 95 years old, primarily Douglas fir and hemlock. The softwood 3 category consists of the very young regenerated softwood, again primarily Douglas fir and hemlock. This category is closer spectrally to hardwood than either of the other two softwood categories. This may be because of the large percentage of ferns, mosses, and grasses present with the young conifers.

Although Level III categories depart somewhat from those set forth in reference 1, the categories defined here represent a useful classification scheme for Site VIII.

2.5 RESULTS OF SITE FAMILIARIZATION

The field trip to Site VIII from September 19 through 23, 1977, by personnel from Lockheed Electronics Company, Inc., NASA/JSC, and the Forest Service provided opportunity for ground observations and analysis. The results of this effort follows.

a. Confusion between hardwoods and softwoods is present. Spectrally, young conifers and hardwoods were nearly identical in the spring when the NASA 1:120 000-scale photographs were taken.

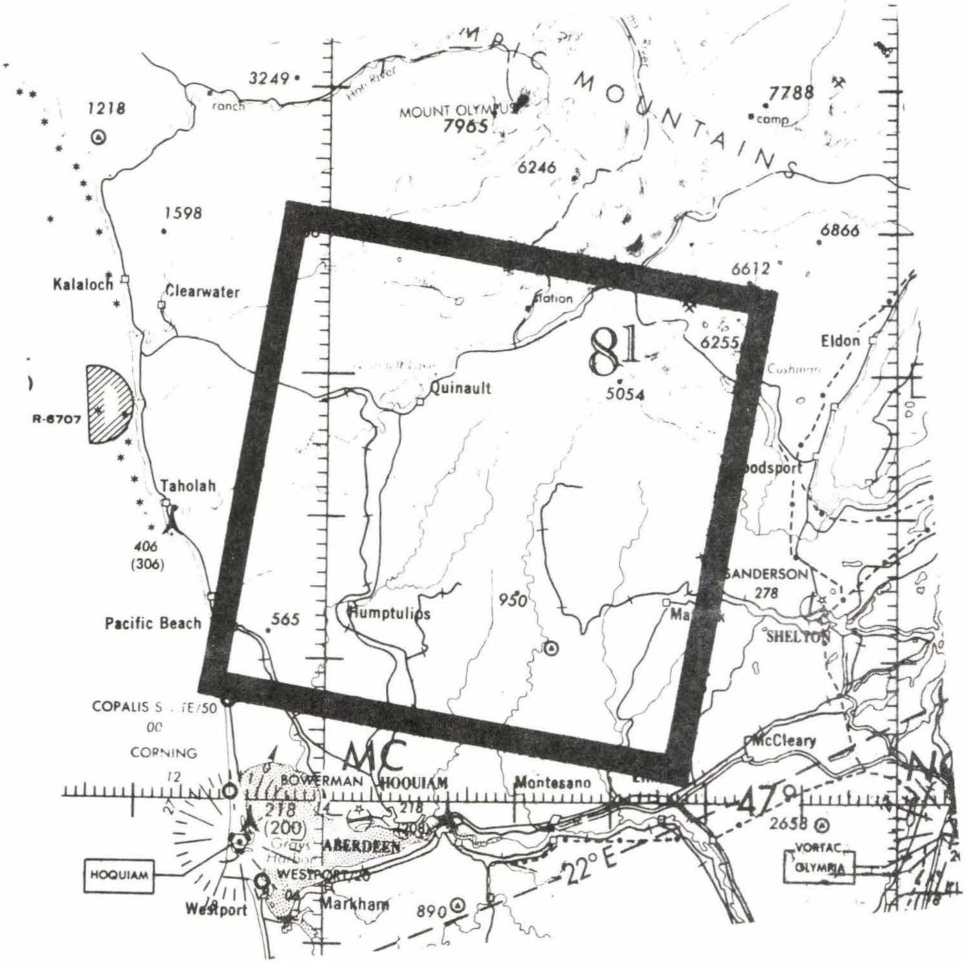
b. Based upon all available information, the dates of photographic and imagery acquisition appear to be critical for the spectral separability of hardwoods from softwoods.

c. The age of the stands appears to have more influence upon the spectral signature than does either species or aspect.

d. Moisture regime is the controlling factor determining the species of softwoods in an area and results in three broad zones of softwoods within Site VIII.

e. Photographs can be more accurately interpreted using the experience and knowledge gained from the field trip.

f. Valuable contacts with the Forest Service and the State of Washington Department of National Resources personnel were established which helped the site scientist.



Scale 1:1 000 000

Figure 2-1.- Location map of Grays Harbor County, Washington, TES site.

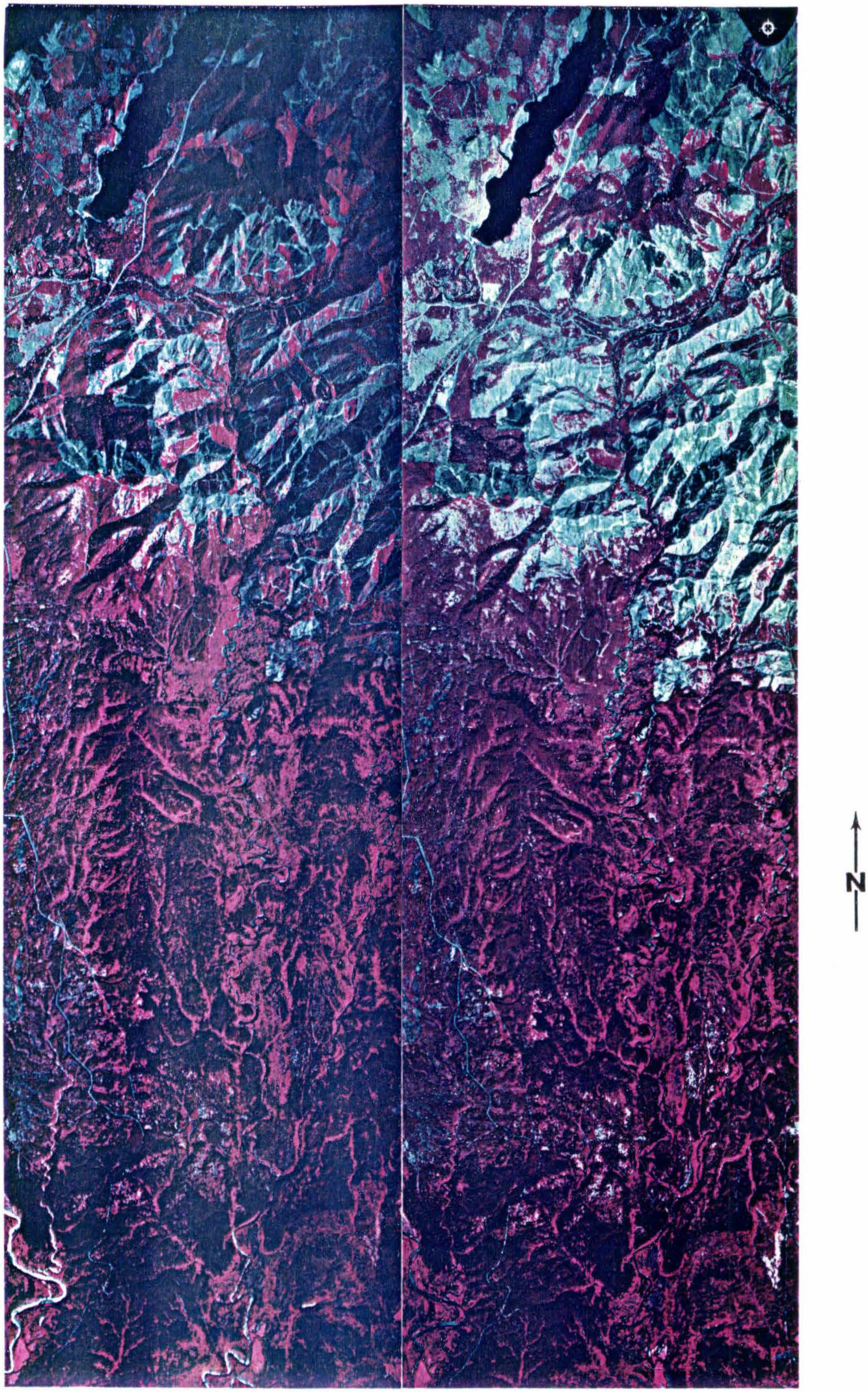


Figure 2-2.- Stereogram of a portion of the aerial photography used in imagery evaluation (scale 1:120 000).

Legend:

Qa **Alluvium:** mostly unconsolidated silt, sand, and gravel valley fill with some clay; includes low-level terrace, marsh, peat, artifical fill, and glacial deposits locally.

Qg$_1$ **Younger glacial drift:** younger glacial drift, undivided; till, outwash, and associated deposits; sorted and unsorted sand, gravel, silt and clay; includes some alluvium.

Qt **Terrace deposits:** unconsolidated to partly consolidated fluvial and glaciofluvial sand and gravel with minor amounts of silt and clay; includes marine terrace along west coast of the Olympic Peninsula.

MP **Miocene-Pliocene marine rocks:** brown-gray, coarsely grained, moderately consolidated, commonly cross-bedded sandstone; grades locally into gritstone and conglomerate lenses; includes minor shale beds; sandstone often shaly and in some areas grades into claystone.

ϕM **Miocene marine rocks:** massive to thinly bedded, friable, basaltic to feldspathic sandstone with shale, siltstone, and local pebble conglomerate interbeds.

M **Oligocene-Miocene marine rocks:** massive to thinly bedded, coarsely grained sandstone, conglomerate, conglomeratic sandstone, shale, and sandy shale.

MzT **Mesozoic-Tertiary marine rocks (undivided):** dark gray, massive to poorly bedded graywacke of the interior Olympic Peninsula; commonly with interbedded slate, argillite, volcanic rocks, and minor arkosic sandstone; includes rocks both older and younger than Ev$_1$, some of which may be Paleozoic.

Ev$_2$ **Middle and lower Eocene volcanic rocks:** dark gray, coarsely to finely grained, strongly chloritized basalt flows and breccia; includes pillow lava, deeply altered palagonite beds, amygdaloidal and vesicular flows, and, locally, sedimentary rocks. Comprises outer volcanic belt in Olympic Peninsula where manganese ore is associated with some submarine lavas.

Ti **Tertiary dikes, sills, and small intrusive bodies:** commonly diabase dikes; generally andesite, porphyry, and dacite plugs and sills.

Thrust fault
Saw-teeth on upper plate

Figure 2-3.– General geological map of Grays Harbor County, Washington.

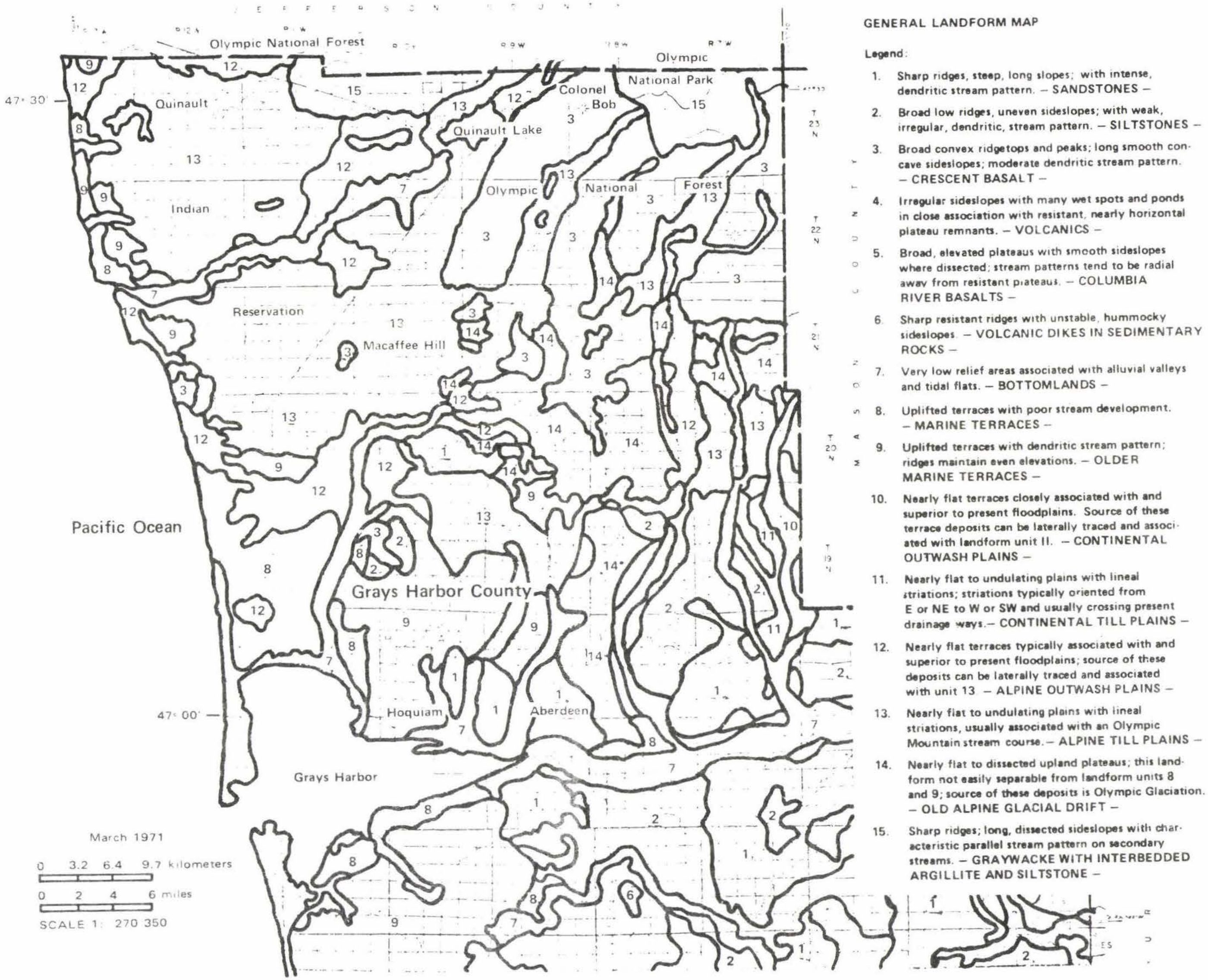
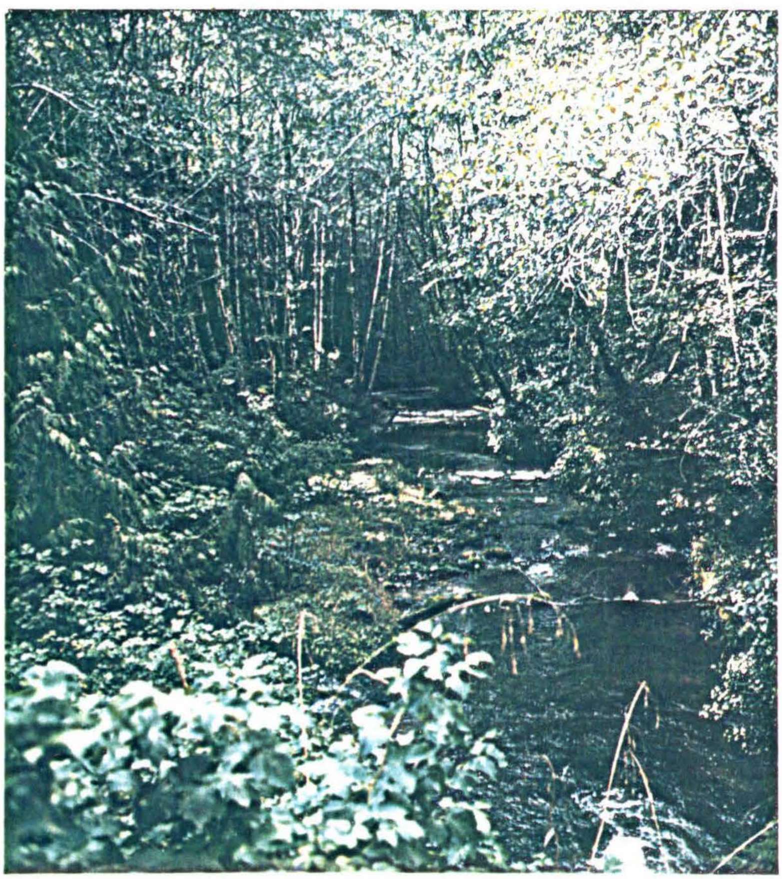


Figure 2-4.– Columbia-Pacific Resource Conservation and Development project map, Grays Harbor, Pacific, and Wahkiakum Counties, Washington.



The stereogram above shows a typical stream and mixed vegetation associated with steep mountain valleys. The trees are western hemlock, western red cedar, and Douglas fir.

A stream and the associated vegetation on the flatter glaciofluvial outwash are shown at left. The trees are primarily red alder.

Figure 2-5.– Typical scenes showing diversity of terrain and vegetation.

Figure 2-6.— Color and color-infrared photographs showing a timber harvest and various stages of regeneration on a portion of the national forest.

Figure 2-7.– Color and color-infrared photographs taken inside a mixed conifer stand. (The stand is in a climax stage.)

Figure 2-8.- Color and color-infrared photographs showing salal surrounding a young Douglas fir seedling.

Figure 2-9. - Color and color-infrared photographs showing initial establishment of vegetation in a clear-cut area. (This area has been burned and is now supporting ferns and brush.)

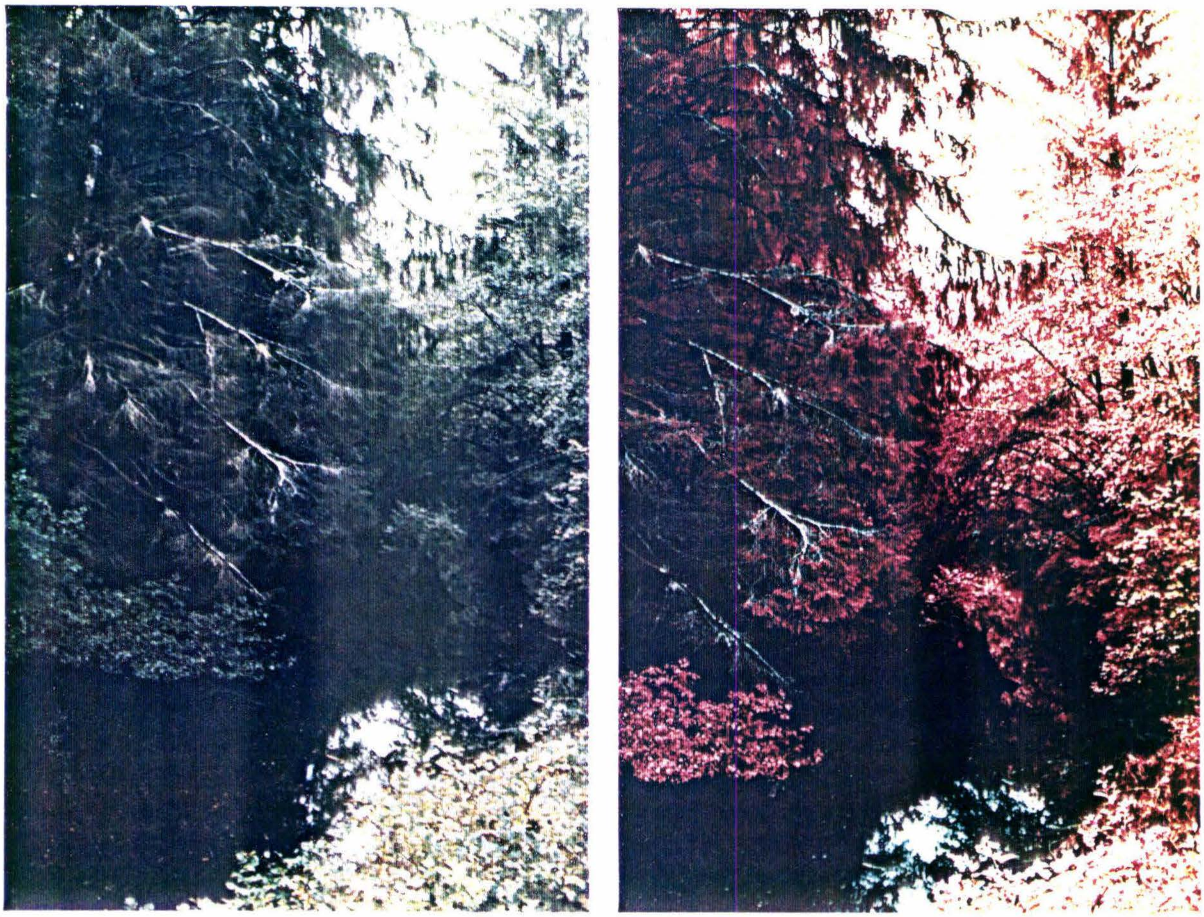


Figure 2-10.— Color and color-infrared photographs showing Sitka spruce (left) and red alder (right) growing on the moist western portion of the site.

Color and color-infrared photographs taken inside a dense alder stand are shown above. The lone conifer is a Sitka spruce.

The color-infrared photograph at left was taken inside a dense stand of Douglas fir growing on the dryer eastern portion of the site.

Figure 2-11.— Comparison of spectral reflectance of alder and Douglas fir.

Figure 2-12.— A portion of an aerial photograph of Quinault Lake, the surrounding national forest, Quinault Indian Reservation, and private commercial forest lands. [The photograph is color infrared (Kodak 2443) at a scale of 1:120 000. It was taken on NASA Mission 73-074A on May 11, 1973.]

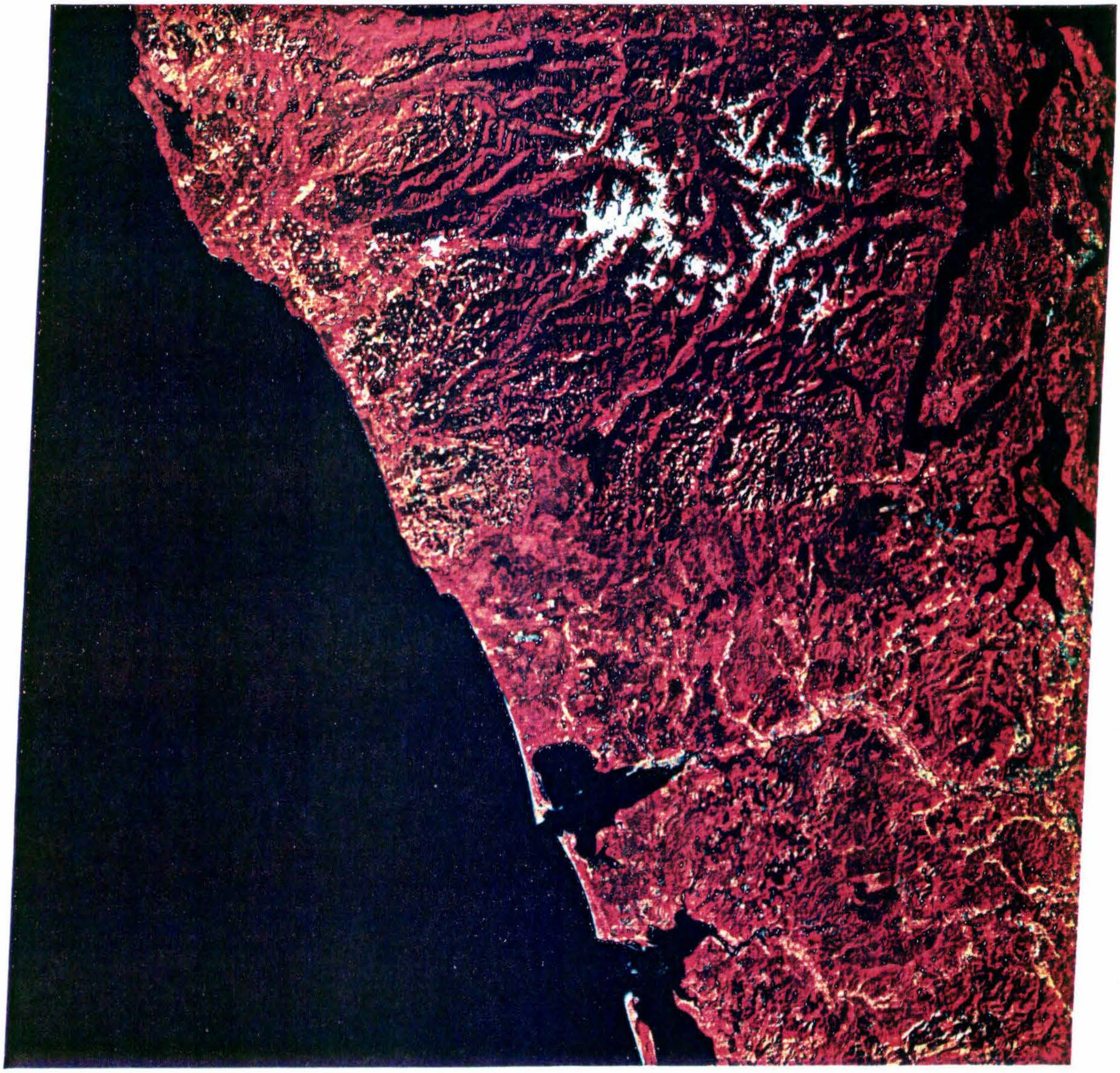


Figure 2-13.— Landsat image, September 12, 1974 (frame number 1781-18272).

3. PREPROCESSING

The preprocessing activity (Task II.2) consists of (1) temporal image-to-image registration of two separate 1000- by 1000-picture element (pixel) Landsat images using the Earth Resources Interactive Processing System (ERIPS), (2) image-to-ground registration of the composite Landsat image using the Image 100, (3) overlaying administrative boundaries on the Landsat image, and (4) delineation of training fields for signature development.

3.1 PROCEDURES

The PMIS/DAS filming of the four quadrants for the September data was completed according to procedures in reference 1. With the exception of overlaying administrative boundaries, the procedures followed in preprocessing were those as outlined in reference 1.

3.2 IMAGE-TO-IMAGE REGISTRATION

The two dates selected for composition of the temporal image were January 1973 and September 1974. These months were selected because they were cloud free and qualified under the procedures in reference 1. The images were composed on the ERIPS into 1000- by 1000-pixel segments. In order to make a temporal image, the two dates must be registered within 1.5 pixels of each other. The registration was done using the Auto-Correlation processor and the Sequential Similarity Detection Algorithm (SSDA) registration program. This algorithm automatically matches points of maximum contrast between the two images and computes transformation equations. A total of 37 control points was used, resulting in a root-mean-square (rms) error of 0.8 pixel with a maximum point shift of 1.4 pixels. The composed image was then written onto tape for display on the Image 100.

3.3 IMAGE-TO-GROUND REGISTRATION

The image-to-ground registration performed on the Image 100 was done differently from the image-to-image registration. Similar control points such as road intersections, lake shorelines, and river meanders were selected from both the imagery and a 1:250 000-scale map. These points were then input into a transformation program which moved the Landsat image so that the image would overlay the 1:250 000-scale map. Thirteen control points were used, resulting in an overall line error of 0.60 pixel and an rms sample error of 1.1 pixels. Running the registration-rotation program resulted in a rotation factor of 0.0694. This factor was used to transform the data to compensate for the Earth's rotation between the top scan line and the bottom scan line.

3.4 OVERLAYING ADMINISTRATIVE BOUNDARIES

Because no county or other significant boundaries fall entirely within Site VIII, only boundaries of the Olympic National Park, the Olympic National Forest, and the Quinault Indian Reservation are on the final map product. No independent statistics are generated for these areas.

3.5 DELINEATION OF TRAINING FIELDS

The selection of training fields for Level II separability study processing was accomplished according to the TES procedures (ref. 1). The selected training fields were generally larger than 2.02 square hectometers (5 acres) and smaller than 16.19 square hectometers (40 acres).

Their selection was based upon a maximum information criterion; i.e., they were selected using the Passive Microwave Imaging System/Data Analysis Station (PMIS/DAS) film transparencies of the Landsat scene, 1:120 000-scale color-infrared photographs,

and ground-truth observations. This method for selecting the training fields did not always select homogeneous training fields. The homogeneity of a particular training field is determined by the classification statistics generated on the Image 100 system at the time of selection. Each training field is displayed, the statistics are calculated, and the scene is alarmed. By alarming the scene, all areas having spectral characteristics similar to the training field are displayed. At this point, if it is determined that the training field is not homogeneous, then shifting the location of the training field is necessary.

4. PROCESSING

4.1 INTRODUCTION

The TES processing procedures (ref. 1) define two studies: a type separability and a simulated inventory.

The purpose of the type separability was to determine the level and accuracy at which the applied procedures of the TES ADP classification could identify and segregate various vegetative types into Level II categories. In the type separability study, training field signatures were derived from the following maximum information data: uniformly distributed training fields based on ground examination, aerial photographs, and Landsat PMIS/DAS transparencies.

For processing, the Level II features of interest were softwood, hardwood, clear-cut, and water. A Level III classification was attempted on a Level II feature only if the Level II training field accuracies for that feature were equal to or exceeded the threshold of 90 percent for softwood, 90 percent for hardwood, 90 percent for water, and 80 percent for clear-cut (ref. 1).

The purpose of the simulated inventory was to obtain a classification of Level II vegetative types using signatures extracted from training fields identified only by the interpretation of the aerial photography which covered a predesignated 10 percent of the study site.

4.2 PROCEDURES

The procedures followed were those outlined in the TES procedures (ref. 1).

4.3 LEVEL II TYPE SEPARABILITY STUDY

The type separability consisted of three activities: spectral signature composition, site classification, and training field classification accuracy assessment. The methods and results of this effort are discussed in the following paragraphs.

4.3.1 SIGNATURE COMPOSITION

All training field signatures for a Level II feature (e.g., softwood) from each of four quadrants of Site VIII were combined to form a supersignature for that category. The supersignature of softwood is the total of four statistics, one statistic for softwood from each of the four quadrants of Site VIII. The supersignature calculation method was used on each of the three data sets: January 1973, September 1974, and temporal (January 1973 plus September 1974).

4.3.2 SITE CLASSIFICATION

The supersignatures of each Level II and Level III category (softwood, hardwood, etc.) for each of the data sets were used to classify the four quadrants of Site VIII. The classifications were used to calculate the proportion of the site covered by a given classification.

4.3.3 TRAINING FIELD CLASSIFICATION ACCURACY ASSESSMENT

The training fields for the Site VIII separability study were selected from the entire site using PMIS/DAS transparencies, 1:120 000-scale color-infrared photographs, and ground observations.

The training field accuracies for each of the three data sets were obtained using the supersignatures for each Level II and Level III category (e.g., softwood). See table 4-1 for Level II and Level III training field classification accuracies.

4.4 LEVEL III SEPARABILITY STUDY

Because the Level II training field accuracies were sufficiently high, a Level III classification was attempted according to procedures set forth in reference 1. The September 1974 separability data were used, and the results are presented in table 4-2.

Training field selection and training field classification accuracy assessment for Level III were done as described for Level II.

Level III training field accuracies (see table 4-1) reflect substantial variance of accuracy within the softwood categories. Less accuracy was obtained for softwood 3 (very young regenerated softwood) than for softwood 2 (pole-to-saw timber stage) or softwood 1 (old growth). The heaviest concentration for softwood 1 and some softwood 2 is in the national forest; the heaviest concentration for softwood 3 and some softwood 2 is in the privately owned lands.

4.5 SIMULATED INVENTORY STUDY

Because the Level II separability study results showed higher training field accuracies for the September 1974 separability, this date was selected for the simulated inventory study.

The training fields were selected from only 10 percent of Site VIII and were selected using PMIS/DAS transparencies and 1:120 000-scale color-infrared photography only. No ground observations were used. The supersignature (derived from 10 percent of the site) was also used for processing the entire site. Calculation results are shown in table 4-1.

Level II total area and relative proportion results are shown in table 4-3.

TABLE 4-1.— TRAINING FIELD ACCURACIES

Feature	Separability study			September simulated inventory, PCC
	January 1973, PCC	September 1974, PCC	Temporal (January 1973 and September 1974), PCC	
<u>Level II</u>				
Softwood	93	99	94	90
Hardwood	89	85	98	96
Clear-cut	89	99	95	98
Water	98	100	99	100
<u>Level III</u>				
Softwood 1		90		
Softwood 2		85		
Softwood 3		72		
Hardwood (Alder)		95		
Improved pasture		100		
Clear-cut		100		
Water		100		

TABLE 4-2.— LEVEL III TRAINING FIELD ACCURACIES, AREA ESTIMATES, AND PROPORTION ESTIMATES FOR THE SEPTEMBER SEPARABILITY STUDY

Feature	Training field accuracy, PCC	Area estimate		Proportion estimate
		Square hectometers	Acres	
Softwood 1	90	32 216.6	79 607.2	0.106
Softwood 2	85	100 847.3	249 193.6	.332
Softwood 3	72	73 728.2	182 182.4	.242
Hardwood	100	18 342.7	45 324.8	.060
Grassland	100	821.0	2 028.8	.003
Water	100	8 603.5	21 259.2	.028
Clear-cut	100	6 957.1	17 191.2	.023
Other		62 705.6	154 945.6	.206

TABLE 4-3.— AREA AND PROPORTION ESTIMATES FOR LEVEL II

Feature	Proportion estimate	Area	
		Square hectometers	Acres
January 1973 separability			
Softwood	0.455	132 140.8	326 520.0
Hardwood	.053	1 546.7	3 822.0
Clear-cut	.096	27 880.2	68 892.0
Water	.110	31 927.5	78 892.8
Other	.333	96 569.4	238 623.2
Total		290 064.6	716 750.0
September 1974 separability			
Softwood	0.707	215 104.2	531 522.4
Hardwood	.062	18 927.7	46 770.4
Clear-cut	.057	17 469.9	43 168.0
Water	.021	6 561.8	15 942.4
Other	.152	46 249.1	114 281.6
Total		304 312.7	751 684.8
January 1973 and September 1974 temporal separability			
Softwood	0.492	173 966.5	429 871.2
Hardwood	.061	21 574.4	53 310.4
Clear-cut	.023	8 169.6	20 188.0
Water	.022	7 941.7	19 624.0
Other	.411	92 332.8	228 154.4
Total		301 985.0	751 148.0
September 1974 simulated inventory			
Softwood	0.544	165 514.0	408 985.0
Hardwood	.082	24 951.5	61 655.2
Clear-cut	.016	4 988.4	12 326.4
Water	.020	6 075.3	15 012.0
Other	.337	102 673.2	253 705.6
Total		304 202.4	751 684.2

5. POSTPROCESSING

The postprocessing activity consists of refining the output classifications from processing; producing final output products in the form of color films, transparencies, prints, and offset prints; and producing evaluation aids. The data manipulation consists of merging the four 485- by 485-pixel classification data into one 970- by 970-pixel classification data tape and postprocessing this 970- by 970-pixel data to produce the final product.

5.1 PROCEDURES

The procedures followed for postprocessing are those given in reference 1 with the following exception; rather than using the Gerber plotter or the Harris offset press as designated, the final product was prepared by a private subcontractor. The classification results used for the postprocessing tasks are from the Site VIII September Level II simulated inventory.

5.2 PMIS/DAS COLOR FILMING

Three sets of color positive transparencies were made on the PMIS/DAS. Each set consists of four frames, each frame representing one-fourth of the site. One set was from the classification tape of the Level III separability study; the second set filmed was the Level II separability study classification tape. This permitted a visual evaluation of the Level II and Level III results. The third set filmed was the color-infrared September Landsat data. The transparency of the third set was used for locating the primary sampling units (PSU's). Figures 5-1 through 5-4 show examples of one quadrant of these data sets. Figure 5-5 is a map showing the location of the 25 PSU's.

5.3 SAMPLE UNIT LOCATIONS

The classified tapes were used to produce alphanumeric printouts of the classification results. These printouts were used in the evaluation process of the study. Twenty-five PSU's, each 50 by 50 pixels in size (835 square hectometers or 2062 acres), were randomly selected on the printout. These PSU's were then transferred to the DAS-produced Landsat color-infrared transparencies and the aerial photographs.

Ten-secondary sampling units (SSU's) were randomly selected from within the 25 PSU's. These SSU's were 2 by 2 pixels (1.33 square hectometers or 3.3 acres) in size. The classification results of the 10 SSU's were compared with the photographically derived ground-truth data of the same area; this was the basis for statistical evaluation of the results. Figure 5-5 shows the location of the 25 PSU's used in this evaluation.

5.4 FINAL OUTPUT PRODUCT

The merged rape containing the Level II inventory classification of all four segments was taken to a private subcontractor who prepared a color-coded classification map of softwood, hardwood, clear-cut, water, and other. The map is produced by a direct image process from the computer tape onto a light-sensitive plate via laser. The plate then goes through a cromalin dusting process to make the final print. This is a new method of preparing map-like results which provides a final product that is much more easily comprehended than the product currently available.

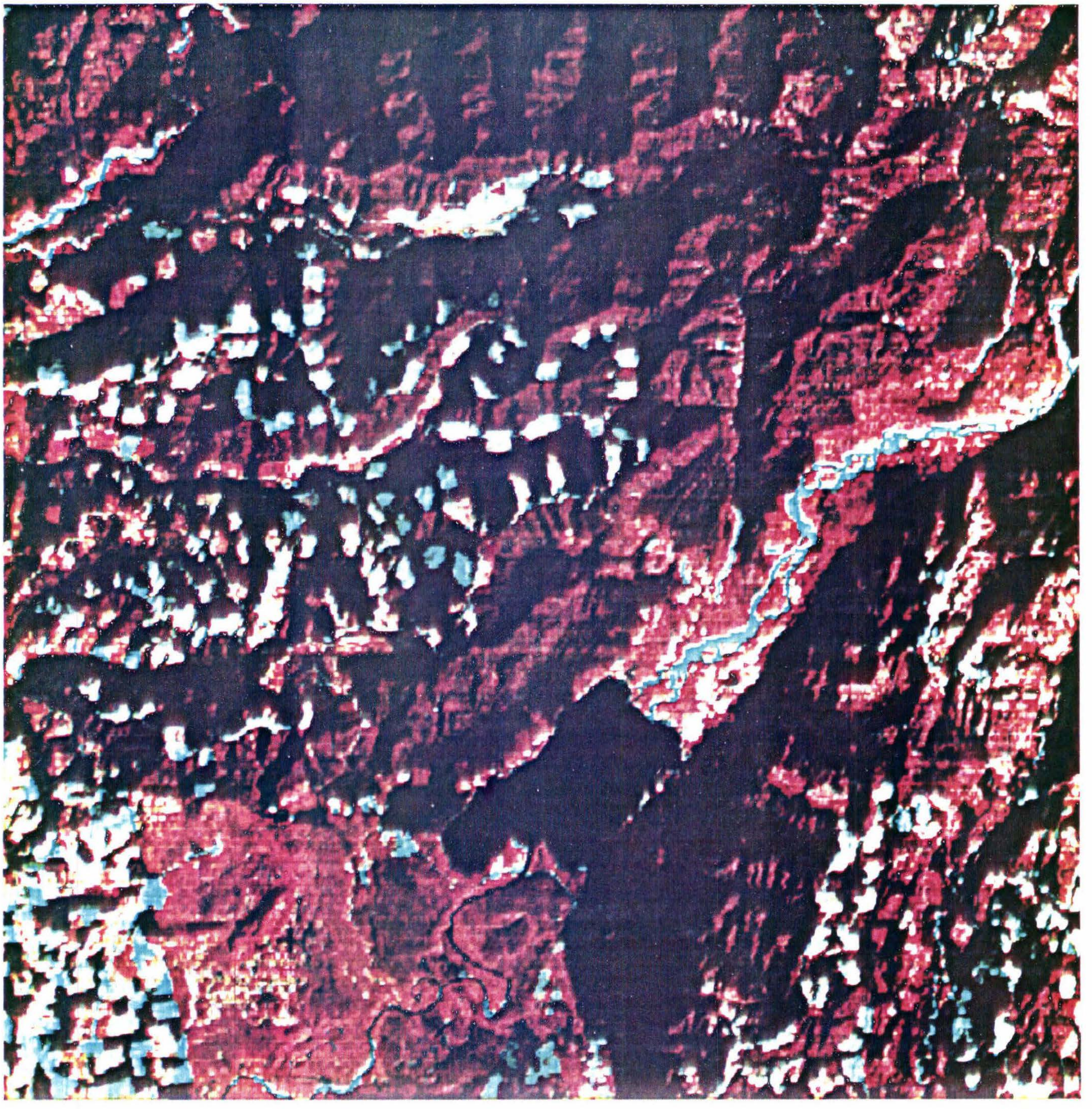
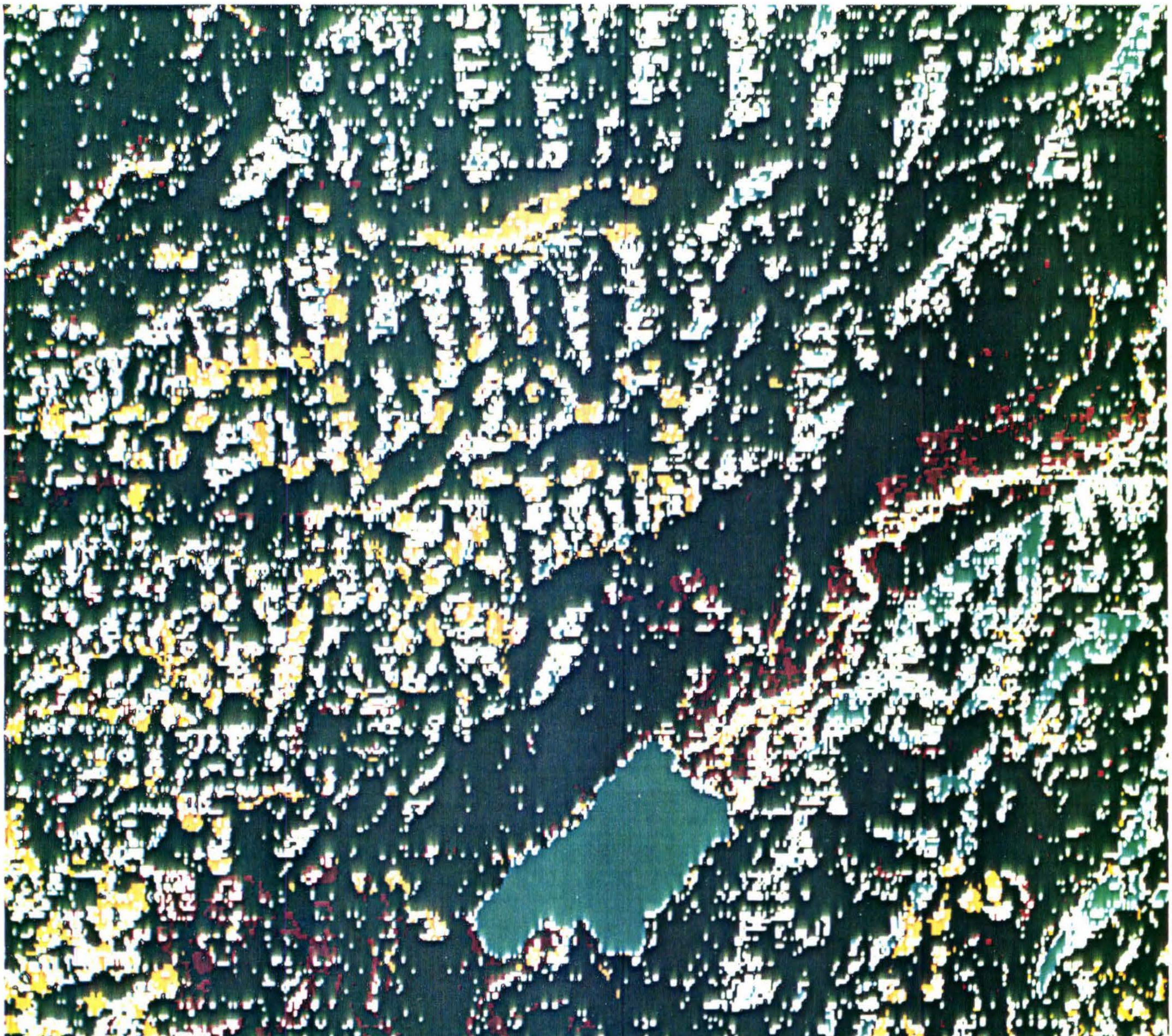


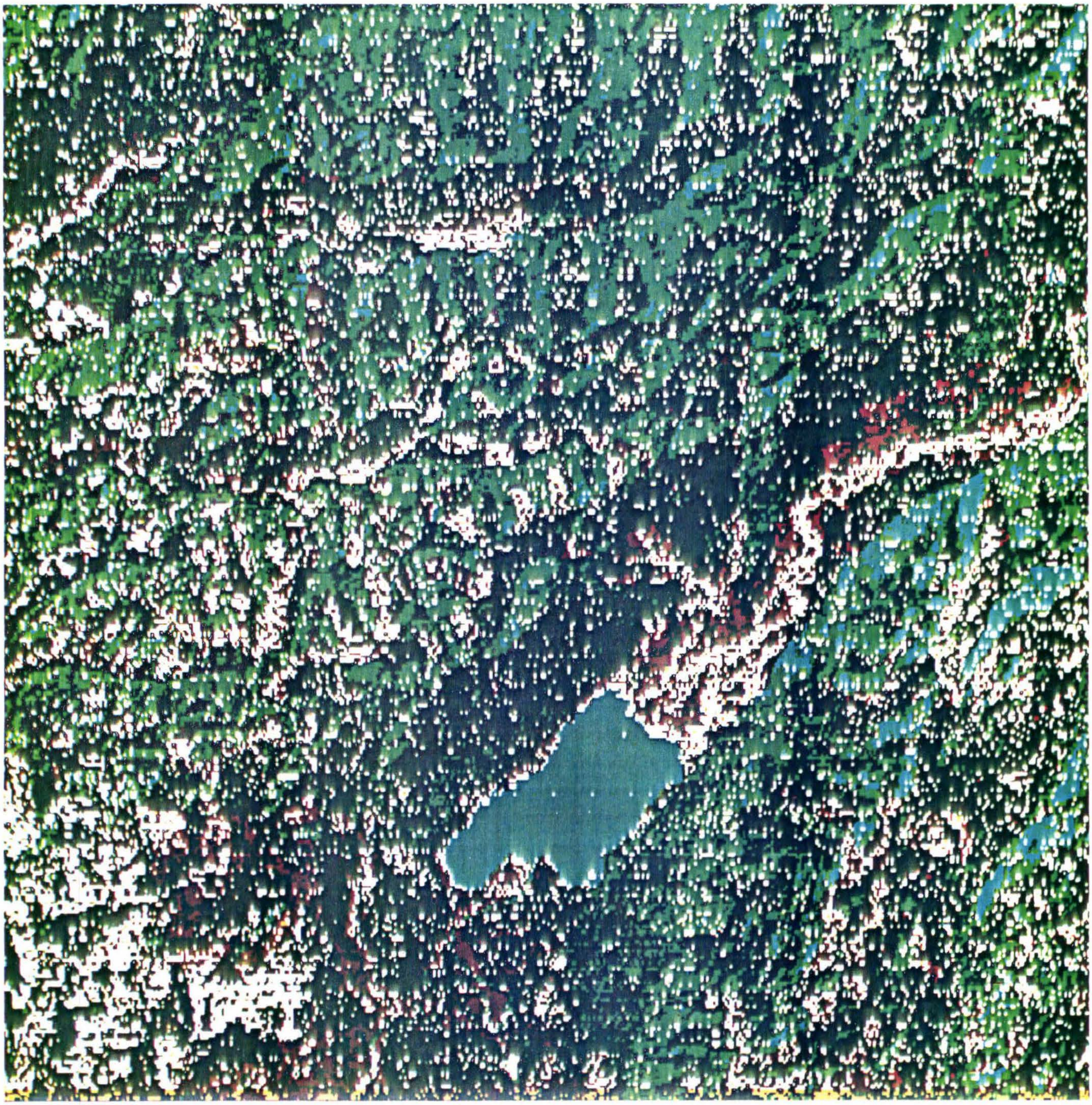
Figure 5-1.— Color-infrared DAS film transparency of quadrant 1 of the September Landsat scene (Landsat channels 2, 3, and 4).



Code:

Green – softwood	Blue – water
Red – hardwood	White – other
Yellow – clear cut	

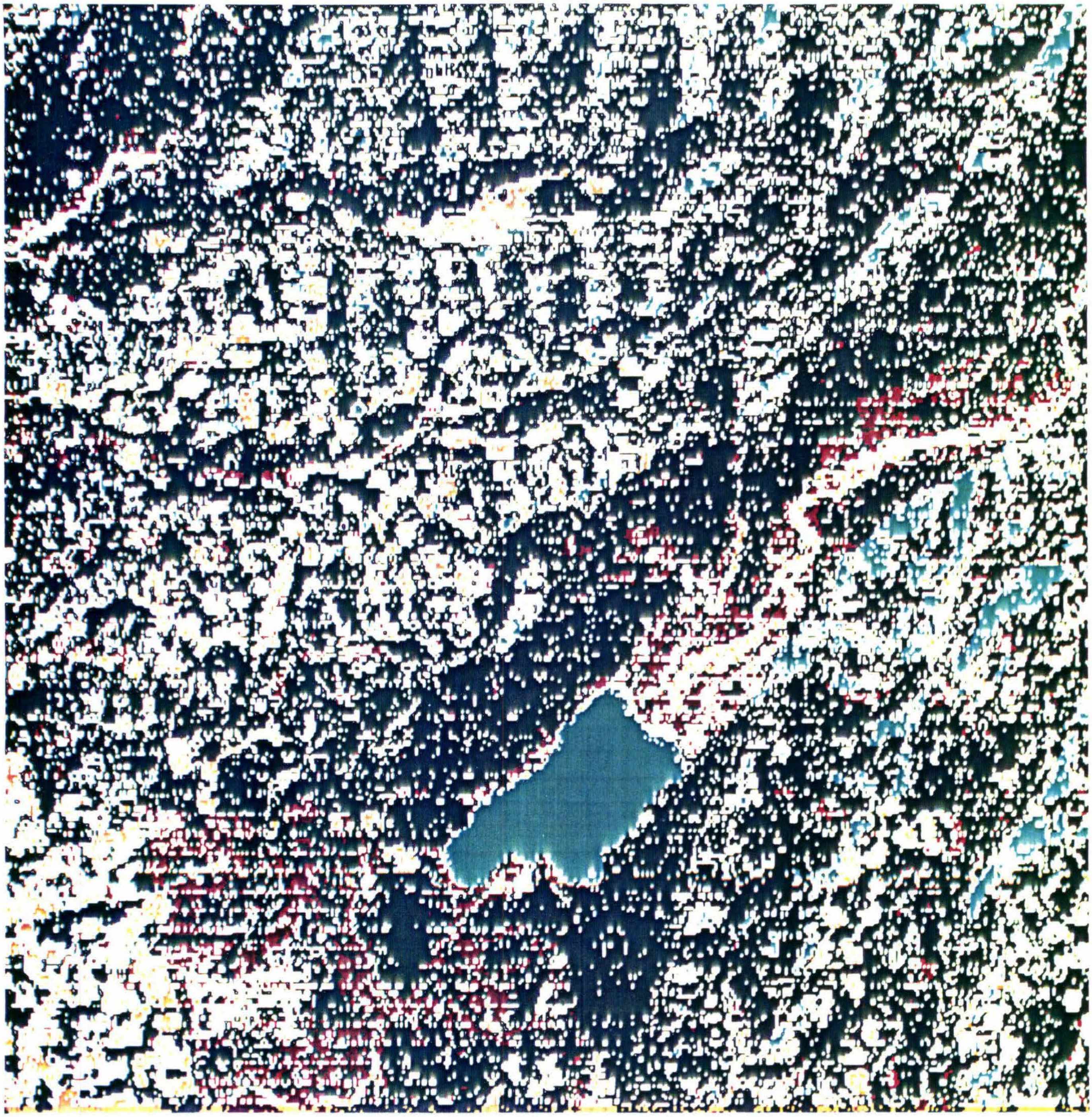
Figure 5-2.– DAS film transparency of quadrant 1 of the September Level II separability study.



Code:

Dark green	– softwood 1	Brown	– clear cut
Green	– softwood 2	Yellow	– pasture/grass
Light green	– softwood 3	Blue	– water
Red	– hardwood	White	– other

Figure 5-3.– DAS film transparency of quadrant 1 of the September Level III separability study.



Code:

Green — softwood
Red — hardwood
Yellow — clear cut
Blue — water
White — other

Figure 5-4.— DAS film transparency of quadrant 1 of the September Level II simulated inventory study.

Figure 5-5.– A map showing location of the 25 PSU's.

6. EVALUATION

Determining the accuracy of the simulated inventory classification map was the task designated for evaluation. This was accomplished using a statistical sampling technique of the inventory classification plus the analysis of the aerial photographs to estimate the overall PCC and its confidence interval, the class proportions, and the average error proportions.

A total of 25 PSU's, 50 by 50 pixels in size, were evaluated. The 25 PSU's were selected on the classification map and located on the corresponding aerial photograph. In each PSU, 10 SSU's (2 by 2 pixels in size) were randomly selected and the computer classification of the SSU's was compared to the photointerpreted classification from the corresponding area on the 1:120 000-scale color-infrared photographs. (The interpretation of the photographs was considered correct.) The SSU classification accuracies were summed to determine the PCC and class proportions for each PSU. The PSU proportions were summed to determine the class proportions for the site.

6.1 PROCEDURES

The procedures followed for evaluation were those set forth in reference 1. Additional procedures for calculating statistics are presented in table 6-1 (refs. 10 and 11).

6.2 EVALUATION RESULTS

For an estimate of the overall PCC and confidence interval calculated for the 25 PSU's, see table 6-2. Table 6-3 shows the average error (deviation) between photointerpretation and ADP along with the confidence interval. In table 6-4, the regression estimate of the class proportion and associated precision is presented. Refer to figure 6-1 for the randomly allocated SSU's in PSU 17 of quadrant 2.

TABLE 6-1.– CALCULATION OF STATISTICS

[From refs. 10 and 11]

General random variable, x	Simulated inventory estimate of proportion, $\hat{p}$	Aerial photographic estimate of proportion, p	Simulated inventory, p_{inv}
$\bar{x}$	$\frac{1}{n}\Sigma\hat{p}_i$	Hand calculator data	Simulated inventory data
s_x^2	$1/n - 1\left[\Sigma\hat{p}_i^2 - \left[(\Sigma\hat{p}_i)^2/n\right]\right]$	Hand calculator data	
$s_{\bar{x}}^2$	s_x^2/n	s_x^2/n	
$s_{\bar{x}}$	$\sqrt{s_{\bar{x}}^2}$	$\sqrt{s_{\bar{x}}^2}$	
$\Delta_{.9}$	$t_{.95(n-1)}s_{\bar{x}}$	$t_{.95(n-1)}s_{\bar{x}}$	
Relative variation	$100\Delta/\bar{x}$	$100\Delta/\bar{x}$	
r^2		Hand calculator data	
m		Hand calculator data	
b		Hand calculator data	
$<p/p_{inv}>$			$mp_{inv} + b$
$s_{<>}^2$			$(1 - r^2)s_p^2\left[\frac{1}{n} + \frac{p_{inv} - \left[(\Sigma p_{inv})/n\right]}{\Sigma\hat{p}_i^2 - \left[(\Sigma\hat{p}_i)^2/n\right]}\right]$
$s_{<>}$			$\sqrt{s_{<>}^2}$
$\Delta_{.9}$			$t_{.95(n-1)}s_{<>}$
Relative variation			$100\Delta/<>$

Symbol definitions:

- b – intercept
- m – slope
- p – aerial photographic estimate of proportion from 25 PSU's
- $\hat{p}$ – simulated inventory estimate of proportion
- p_{inv} – simulated inventory sample estimate from 25 PSU's
- $<p/p_{inv}>$ – regression estimate of proportion
- r^2 – coefficient of determination
- s_x^2 – variance of the sample
- $s_{\bar{x}}^2$ – variance of the mean
- $s_{\bar{x}}$ – standard deviation of the mean
- $s_{<>}$ – standard error of the estimate
- $s_{<>}^2$ – variance of the estimate
- t – Fisher's t-distribution (Student's t)
- x – general random variable
- $\bar{x}$ – arithmetic mean
- $\Delta_{.9}$ – half-confidence interval
- $100\Delta/\bar{x}$ – relative variation of the mean
- $100\Delta/<>$ – relative variation of the estimate

TABLE 6-2.— ESTIMATED PCC AND CONFIDENCE INTERVAL AT THE 90-PERCENT CONFIDENCE LEVEL FOR 25 PSU'S

Inventory	PCC	Half-confidence interval, $\Delta_{.9}$	PCC $\pm$ $\Delta_{.9}$
25 PSU's	71.6%	±6.7%	64.9 to 78.3%

TABLE 6-3.— AVERAGE ERRORS BETWEEN CLASS PROPORTION ESTIMATES FROM AERIAL PHOTOINTERPRETATION AND LANDSAT ADP INVENTORY CLASSIFICATION

Feature	Inventory, 25 PSU's[a]			
	Photograph class proportion, p	ADP class proportion, $\hat{p}$	Average error, B	Confidence interval, B $\pm$ $\Delta_{.9}$
Softwood	0.614	0.584	0.030	(-0.018, 0.078)
Hardwood	.103	.074	.029	(-.004, .062)
Clear-cut	.070	.032	.038	(.007, .069)
Water	.004	.004		(-.008, .008)
Other	.209	.306	-0.097	(-.137, -.057)

[a]These 25 PSU's were randomly located within the site.

TABLE 6-4.— REGRESSION ESTIMATES OF CLASS PROPORTION AND ASSOCIATED PRECISION

Feature	Simulated inventory proportion, p_{inv}	Regression estimates of proportion, $\langle p/p_{inv} \rangle$[a]	Coefficient of determination, r^2	Variance of the estimate, $s^2_{\langle\rangle}$	Half-confidence interval, $\Delta_{.9}$	Percent relative variation, $100\Delta/\langle p/p_{inv} \rangle$
Softwood	0.544	0.579063	0.64574	0.000817	0.048906	8.45
Hardwood	.074	.111653	.46374	.000410	.034646	31.03
Clear-cut	.032	.057966	.20448	.000352	.032120	55.41
Water[b]	.004	.002082	.00497	.000046	.011635	558.9
Water[c]	.020	.020	0.0	.000063	.013553	67.76

[a]The conditional expectation of p, given p_{inv}.

[b]Unconstrained regression.

[c]Regression with intercept through origin.

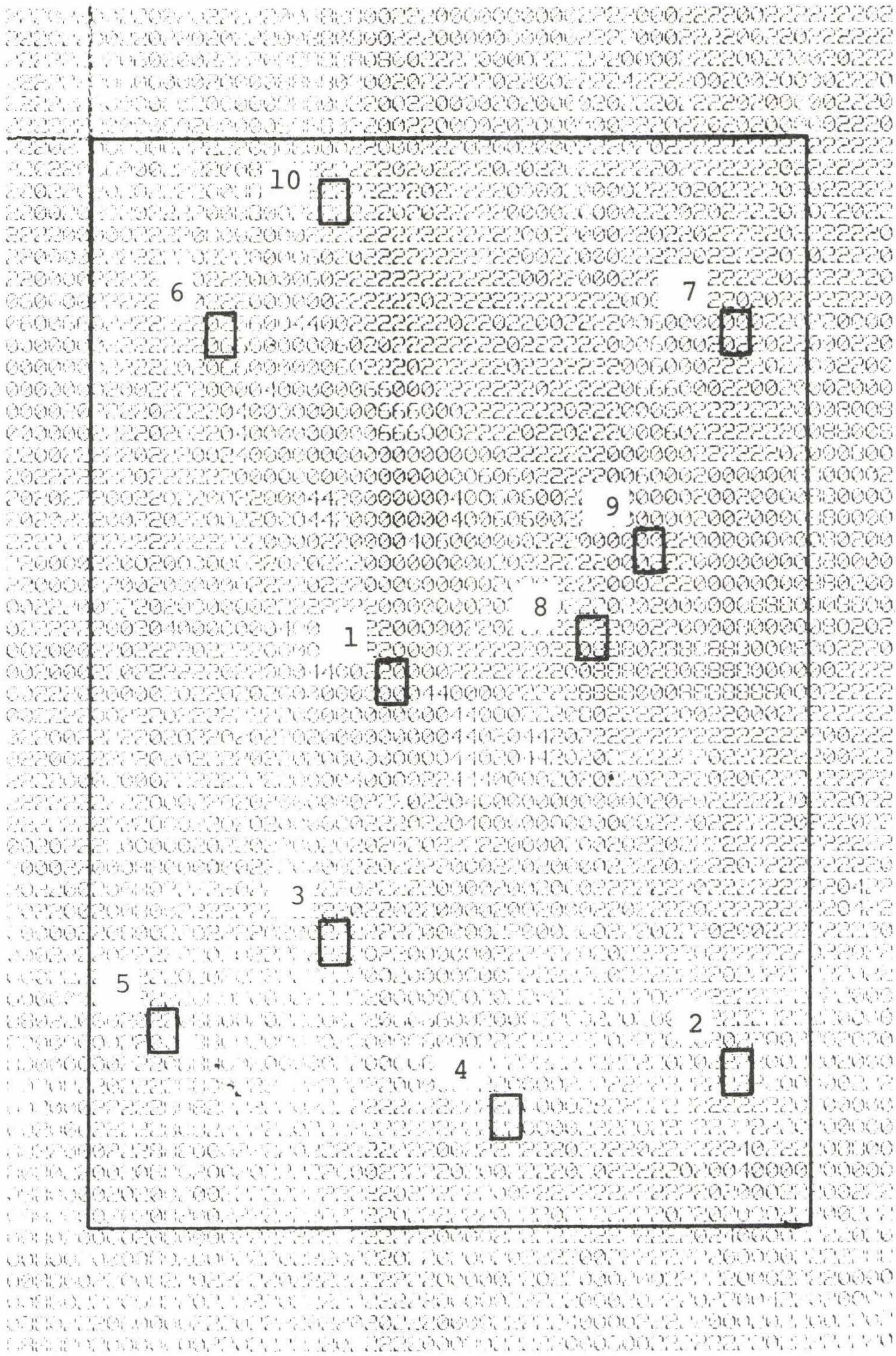


Figure 6-1.— The PSU 17, quadrant 2, showing
the random allocation of SSU's.

7. DIRECT RESOURCE UTILIZATION

The resources required for this study included: site data (Landsat imagery, aerial photography, and ancillary information), machine and equipment time, and manpower.

Throughout the period of study, strict hourly records were kept on man-hours and machine time expended. These are listed in table 7-1. Table 7-2 reveals the breakdown of the hourly costs for machine time and manpower plus overhead costs. A comparison of the total costs with the total land area shows that the direct costs amounted to 16.84 cents per square hectometer (6.8 cents per acre).

Overhead costs in this report include the costs of eight color composite Landsat frames; the Landsat scenes in the form of computer-compatible tapes; the color-infrared aerial photographs from NASA Mission 73-074A (flown May 11, 1973); and transportation, food, and lodging for the four people who visited Site VIII. Such costs as administration, project planning, and purchase of equipment are not part of the overhead costs described in this report.

For work to be performed on future sites and in a production mode, the cost might be considerably less if the analysts were familiar with the site and the data processing procedures. Inflation will affect the costs of machine time and labor. This could be overcome by projecting cost estimates and then applying a percentage factor for inflation to the basic costs.

TABLE 7-1.— RESOURCES UTILIZED FOR SITE PROCESSING

Task	Man-hours	Actual machine hours				
		Bausch & Lomb zoom transfer scope	ERIPS	Image 100 interactive analysis	PMIS/DAS image composition	Dell Foster digitization
Preliminary image analysis	76					
Site analysis	509					
Preprocessing	180		16	33		6
Processing	130			45	2	
Postprocessing	102			6	10	15
Evaluation	216	12				
Reporting	[a] 158					
	80					
	80					
	170					
Total hours	1701	12	16	84	12	21

[a]See references 9, 12, and 13.

TABLE 7-2.– DIRECT COSTS FOR MACHINE TIME AND MAN-HOURS

Item	Cost per hour	Hours	Subtotal	Total
System:				
Image 100	$300.00	84	$25 200.00	
ERIPS	300.00	16	4 800.00	
PMIS/DAS	100.00	12	1 200.00	
Dell Foster	15.00	21	315.00	
Total				$31 515.00
Man-hours:				
Salary	$ 8.75[b]	1701	$14 883.75	
Overhead	3.68[b]	1701	6 259.68	
Total				$21 143.43
Total direct cost[a]				$53 658.43

[a]At an average cost of 16.84 cents per square hectometer (6.8 cents per acre).

[b]Average rate estimated by informal government source. This does not necessarily correlate with the actual rates used for this study.

8. ANALYSIS OF RESULTS

8.1 INTRODUCTION

Consideration was given to the following items during the analysis phase of the work performed for Site VIII.

a. The effect of environmental factors on the data processing results

b. The levels of classification and associated accuracy

c. The best seasons for acquiring data that segregate vegetative types correctly

d. The extent that regression transformations help classification accuracies when applied to the classification results

e. The unique characteristics of the vegetative association within Site VIII

The discussion of these items is included in section 8.2. Refer to tables 8-1 through 8-4 for the simulated inventory and photographic sample data results for softwood, hardwood, clear-cut, and water. Levels I and II proportion estimates are in table 8-5.

The results of the proportion estimates obtained during this site study are presented graphically in figures 8-1 through 8-4 and are discussed in section 8.2. The line numbers in these figures present estimates of separability, inventory sample, aerial photographic sample, and regression.[2] A description of these estimates and their usage follows.

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[2]The regression estimate is the conditional expectation of the average of all photographic PSU estimates given the value of the inventory estimate.

Line number	Description	Use
1	Separability proportion estimates of the given class for the three dates and the ADP simulated inventory estimate	Visual comparison of the three separability estimates and the simulated inventory estimate
2	ADP simulated inventory sample estimate and its 90-percent confidence interval	Comparison of the results of the simulated inventory sample estimate with both the simulated inventory estimate and the separability estimate of the same date; comparison of the position of the line 1 elements with the line 2 confidence interval
3	Aerial photograph sample estimate and its 90-percent confidence interval	Comparison of the results of the aerial photograph sample estimate with the elements of lines 1 and 2; visual representation of its confidence interval; representation of the regression transformation between the line 2 and line 3 sample estimates by an arrow labeled R
4	ADP simulated inventory estimate	Application of the regression transformation (R) to the inventory proportion
5	Regression estimate, its 90-percent confidence interval, and the corresponding separability estimate	The *a priori* expected regression transformation, based on the assumed maximum information status of the separability estimate, represented by a dashed-line arrow between the simulated inventory estimate (line 4) and the separability estimate for the same date (line 5)

8.2 LEVEL OF CLASSIFICATION ACCURACIES AND REGRESSION ANALYSIS

8.2.1 ANALYSIS OF SOFTWOOD

Separability and inventory proportion estimates for softwood (fig. 8-1, line 1) range from 0.435 to 0.707. (The desired range of data was closer.) The January 1973 and September 1974 separability data show a tremendous variance. The explanation for this may be the low Sun angle during the month of January, resulting in more prevalent shadows on the January data than on that of September. These shadows were classified as water on the January data, and the resulting softwood proportion was significantly lower for January than for September. The shadows on one date affected the supersignature sufficiently to cause the shadowed area to be classified as water.

The September simulated inventory data reflect the softwood proportion to be 0.544. (This proportion was expected to be closer to the separability study results.) The supersignature derived from the 10-percent training field area was not sufficiently representative to classify all of the softwoods. The simulated inventory sample estimate for softwood with its 90-percent confidence interval is 0.584 ± 0.075 or ±12.85 percent relative (fig. 8-1, line 2).

The softwood sample estimate from photointerpretation with its 90-percent confidence interval is 0.614 ± 0.081 or ±13.16 percent relative (fig. 8-1, line 3). This sample estimate correlates with neither the September simulated inventory nor the separability estimate. The 25 randomly selected PSU's were deficient in mature softwood stands.

The regression estimate for softwood with its 90-percent confidence interval is 0.579 ± 0.049 or ±8.45 percent relative. For softwood, the regression transformation corrects the September inventory estimate toward the separability estimate; however, it

does not transform the estimate sufficiently. In figure 8-1, the dashed line between lines 4 and 5 represents the expected or desired regression transformation.

8.2.2 ANALYSIS OF HARDWOOD

The hardwood January 1973 separability data (fig. 8-1) have the lowest proportion estimate. Shadows resulting from a low Sun angle and hardwood not registering because trees were in a leaf-off condition are the reasons for the low estimate.

The temporal separability data reflect a higher proportion estimate of hardwood than either the January 1973 or September 1974 separability data. An explanation for this is not readily apparent. It was expected that the temporal data would show proportion estimates between those of the January and September separability proportions. One explanation may be a misregistration problem where, for example, a hardwood training field overlaps a field of another class, resulting in broader spectral bounds for the hardwood supersignature.

The September 1973 simulated inventory data have the highest proportion estimate of all three data sets (January 1973, September 1974, and temporal simulated inventory). A reason for this may be an unusually large quantity of hardwood within the 10-percent area selected for the training field. Also, many young conifers (softwood) exhibited spectral bounds similar to that of hardwood, resulting in a supersignature that is not spectrally homogeneous.

The September inventory sample estimate with its 90-percent confidence interval is 0.074 ± 0.029 or ±39.13 percent relative (fig. 8-2, line 2). Estimates from all three data sets fall within the 90-percent confidence interval, which indicates they are a close representation of the inventory training field area

for hardwood even though the hardwood supersignatures may not have been spectrally homogeneous.

The photographic sample estimate with its 90-percent confidence interval is 0.103 ± 0.047 or ±45.81 percent relative (fig. 8-2, line 3). This appears high. Perhaps the 25 randomly selected PSU's were located in the hardwood-rich areas, which would give a higher hardwood estimate than expected.

Applying the regression transformation to the inventory estimate results in the regression estimate with its 90-percent confidence interval of 0.112 ± 0.035 or ±31.03 percent relative (fig. 8-2, line 5). The dashed line with arrow between lines 4 and 5 in figure 8-2 shows the expected regression transformation. The regression equation transforms the results away from the expected result. The randomly selected PSU's may have been in areas with large quantities of hardwood; thus, the photographic sample estimate would indicate the larger hardwood proportion.

The September separability estimate, with training fields derived from a maximum information base, is assumed to be closer to the actual proportion of hardwood in Site VIII.

8.2.3 ANALYSIS OF CLEAR-CUT

For this study, clear-cut is defined as a previously forested area now exhibiting bare soil signatures. Because there is no appreciable area of natural bare soil, all bare soil areas were classified as clear-cut. However, areas that were clear-cut and then regenerated with some form of vegetative cover ceased to be clear-cut signatures. These areas were then classified as softwood, hardwood, or unclassified, thus falling into the category of other.

The January separability estimate had the highest relative proportion and the September simulated inventory study the lowest (see fig. 8-3). The reasons for the high relative proportion of 0.920 in January may be the season and weather. The hardwoods are in a leaf-off condition in January, and light snow is evident in the higher elevations causing a signature response of clear-cut instead of hardwood.

Because of the logging activity in the area, the September simulated inventory proportion for clear-cut was expected to be higher than that exhibited by the data. Perhaps the 10-percent area used for inventorying did not have a representative sample of clear-cut from which to build training signatures.

The simulated inventory sample estimate with its 90-percent confidence interval is 0.032 ± 0.062 or ±195.2 percent relative, indicating confusion in the clear-cut category (fig. 8-3, line 2). The photographic data were acquired in May 1973, and the September Landsat imagery was taken in 1974. The amount of regeneration between the two data sets was sufficient to cause correlation problems. Previously clear-cut areas now had vegetative cover, and areas previously forested were clear-cut.

The aerial photointerpretation estimate with its 90-percent confidence interval is 0.070 ± 0.036 or ±50.95 percent relative (fig. 8-3, line 3). This is within reason.

The regression estimate with its 90-percent confidence interval is 0.058 ± 0.032 or ±55.41 percent relative (fig. 8-3, line 4). Applying the regression equation to the simulated inventory estimate resulted in an inventory statistic close to the September separability proportion based on maximum information. Thus, the regression estimate seems reasonable.

8.2.4 ANALYSIS OF WATER

The analysis of water estimates offered surprises. The statistical distribution of points [the set of PSU points ($\hat{p}$ = simulated inventory sample estimate and p = aerial photographic sample estimate)] should be observed for effective evaluation of water estimates. Refer to figures 8-4, 8-5, and table 8-4. The water proportion estimate with its 90-percent confidence interval is 0.004 ± 0.004 or ±101.2 percent relative (fig. 8-4, line 2).

The coefficient of determination (r^2) for the regression was a mere 0.00497; or, only 0.5 percent of the sum squares about the mean $\bar{p}$ was explained (or removed) by the regression. The slope of the regression line was negative, -0.11940, indicating a negative correlation between the photographic sample estimate for water and the corresponding inventory sample. These astonishing results are mathematically and statistically correct, but hardly comformable with nature.

A more realistic and theoretically conformable model may be obtained by requiring the regression line to pass through the origin and, as usual, through the centroid of the distribution $(\bar{\hat{p}}, \bar{p})$. With this set of points, the variance about the regression line is the same as the sum of the variances $\left(s^2_{\hat{p}} + s^2_{p}\right)$. The final result for the regression estimate of the water proportion with its 90-percent confidence interval would then be 0.020 ± 0.014 or ±67.76 percent relative, a considerable improvement over the initial unconstrained regression estimate. This estimate compares well with the September separability estimate of 0.021 for water.

8.2.5 ANALYSIS OF OTHER

The category of other does not constitute a class in the TES classification system. No training fields were selected nor any

signatures built. Rather, the category of other consists of the unclassified pixels. Thus, other is a heterogeneous mix of all the classes as well as those features for which no training fields were selected.

A subjective photointerpretation evaluation of the PMIS/DAS film transparencies of both the Level II and Level III classifications shows the concentration of other to be associated with previously clear-cut areas. This indicates that other is a heterogeneous mix of all types of vegetation associated with regeneration after the clear-cutting of an area.

For Site VIII, the category of other had a proportion estimate higher than desired. The only feasible way to reduce this proportion estimate is to reduce the resolution of the Image 100 so that all pixels will be classified into some class. To do this may cause the classes to overlap; i.e., some hardwoods classified as softwood and some softwoods classified as hardwood. Thus, the homogeneity of signatures is not pure. Homogeneous signatures are necessary to keep training field separability at a maximum, and training field separability at a maximum is necessary to maintain the PCC of the training fields above the threshold set forth in reference 1.

A complete study of the phenomena of the category of other will have to be done before any viable method of classification of all features can be incorporated into inventory systems such as TES.

8.3 SUMMARY

The evaluation of the inventory study reflects an estimated PCC range of 64.9 to 78.3 at the 90-percent confidence level. The desired PCC range was 85 to 95 percent with a tighter 90-percent confidence interval.

Before concluding that the PCC for inventory is unreasonably low, consideration should be given to the following factors. Steep mountains, low valleys, and heterogeneous vegetation characterize Site VIII. The low Sun angle casts shadows in the valleys, which tend to classify as water. The low Sun angle also affects the softwood signature response of the forests on the mountain slopes. For example, the Level III classifications of softwood 1 and 2 indicate some interpretation confusion in signature response. Softwood 1 (very old) registers more prevalent on the north-facing slopes, and softwood 2 (less old) registers more prevalent on the south-facing slopes. This vegetative change may be associated with aspect (north and south orientation); however, no definite correlation was found during the field trip. The Sun angle is probably the reason for the vegetative differences on the north and south slopes.

The age of a softwood class does seem to have validity in classifying Level III softwood 3, which is the youngest regeneration. Softwood 3 is found most frequently on land that has been recently disturbed by forest management practices.

Interpretation confusion caused by the elapse of time between aerial photographic coverage of Site VIII and the Landsat data used for the inventory classification (approximately 1 year) was significant. One area shows forests on the aerial photographic coverage and clear-cut on the September Landsat data. Some areas show clear-cut on the aerial photographic coverage, yet have regenerated sufficiently to be classified as other.

Adding to the interpretation confusion were large areas of privately owned lands which were clear-cut in the past. For some reason, these areas are still scrub, supporting few conifers. The areas may not have been replanted and were too far

from the natural conifer seed source to regenerate to conifers. Clear-cutting may have altered the chemical or moisture balance, thus hindering conifer reestablishment.

Another concern when evaluating the reasonableness of the PCC for inventory is the quantitative sample from which signatures were derived. The inventory sample estimates were based on signatures from 10 percent of a quadrant, and ground-truth data were based only on aerial photointerpretation. The area was not visited by the site scientist. The assumption that aerial photointerpretation is correct may not be valid. If consideration is given to these factors, the PCC range appears reasonable.

The separability results are assumed to be more accurate because the signatures used were derived from the maximum information available. A visual evaluation of the separability study results (both Levels II and III) supports this hypothesis; however, the separability estimates were not subjected to the same evaluation techniques as were the simulated inventory estimates. Thus, no quantitative comparison of the results of these studies is available, and the evaluation of the best estimate is subjective.

TABLE 8-1.— INVENTORY AND PHOTOGRAPHIC SAMPLE DATA FOR SOFTWOOD PROPORTIONS

General random variable, x	Inventory estimate proportion, $\hat{p}$	Aerial photographic estimate of proportion, p	Simulated inventory, p_{inv}
$\bar{x}$	0.584	0.6136	0.544
s_x^2	.048067	.055724	
$s_{\bar{x}}^2$	.001923	.002229	
$s_{\bar{x}}$	.043848	.047212	
$\Delta_{.9}$	.075025	.080779	
$100\Delta/\bar{x}$	12.85%	13.16%	
r^2		.64574	
m		.86313	
b		.10952	
$\langle p/p_{inv} \rangle$			.579063
$s_{\langle\rangle}^2$			.000817
$s_{\langle\rangle}$			.028583
$\Delta_{.9}$			.048906
$100\Delta/\langle\rangle$			8.45%

Symbol definitions:

b	– intercept
m	– slope
p	– aerial photographic estimate of proportion from 25 PSU's
$\hat{p}$	– simulated inventory estimate of proportion
p_{inv}	– simulated inventory sample estimate from 25 PSU's
$\langle p/p_{inv} \rangle$	– regression estimate of proportion
r^2	– coefficient of determination
s_x^2	– variance of the sample
$s_{\bar{x}}^2$	– variance of the mean
$s_{\bar{x}}$	– standard deviation of the mean
$s_{\langle\rangle}$	– standard error of the estimate
$s_{\langle\rangle}^2$	– variance of the estimate
t	– Fisher's t-distribution (Student's t)
x	– general random variable
$\bar{x}$	– arithmetic mean
$\Delta_{.9}$	– half-confidence interval
$100\Delta/\bar{x}$	– relative variation of the mean
$100\Delta/\langle\rangle$	– relative variation of the estimate

TABLE 8-2.– INVENTORY AND PHOTOGRAPHIC SAMPLE DATA FOR HARDWOOD PROPORTIONS

General random variable, x	Inventory estimate proportion, $\hat{p}$	Aerial photographic estimate of proportion, p	Simulated inventory, p_{inv}
$\bar{x}$	0.074	0.1028	0.082
s_x^2	.007160	.18938	
$s_{\bar{x}}^2$	.000286	.000758	
$s_{\bar{x}}$	.016923	.027523	
$\Delta_{.9}$	.028956	.047092	
$100\Delta/\bar{x}$	39.13%	45.81%	
r^2		.46374	
m		1.10747	
b		.02084	
$< p/p_{inv} >$			.111653
$s_{< >}^2$			.000410
$s_{< >}$			.020249
$\Delta_{.9}$			.034646
$100\Delta/< >$			31.03%

Symbol definitions:

- b – intercept
- m – slope
- p – aerial photographic estimate of proportion from 25 PSU's
- $\hat{p}$ – simulated inventory estimate of proportion
- p_{inv} – simulated inventory sample estimate from 25 PSU's
- $< p/p_{inv} >$ – regression estimate of proportion
- r^2 – coefficient of determination
- s_x^2 – variance of the sample
- $s_{\bar{x}}^2$ – variance of the mean
- $s_{\bar{x}}$ – standard deviation of the mean
- $s_{< >}$ – standard error of the estimate
- $s_{< >}^2$ – variance of the estimate
- t – Fisher's t-distribution (Student's t)
- x – general random variable
- $\bar{x}$ – arithmetic mean
- $\Delta_{.9}$ – half-confidence interval
- $100\Delta/\bar{x}$ – relative variation of the mean
- $100\Delta/< >$ – relative variation of the estimate

TABLE 8-3.– INVENTORY AND PHOTOGRAPHIC SAMPLE DATA FOR CLEAR-CUT PROPORTIONS

General random variable, x	Inventory estimate proportion, $\hat{p}$	Aerial photographic estimate of proportion, p	Simulated inventory, p_{inv}
$\bar{x}$	0.032	0.0704	0.016
s_x^2	.033311	.010987	
$s_{\bar{x}}^2$	.001332	.000439	
$s_{\bar{x}}$	.036502	.020964	
$\Delta_{.9}$	.062456	.035869	
$100\Delta/\bar{x}$	195.2%	50.95%	
r^2		.20448	
m		.77662	
b		.04554	
$\langle p/p_{inv} \rangle$			.057966
$s_{\langle\rangle}^2$			.000352
$s_{\langle\rangle}^2$			.018773
$\Delta_{.9}$			.032120
$100\Delta/\langle\rangle$			55.41%

Symbol definitions:

b – intercept

m – slope

p – aerial photographic estimate of proportion from 25 PSU's

$\hat{p}$ – simulated inventory estimate of proportion

p_{inv} – simulated inventory sample estimate from 25 PSU's

$\langle p/p_{inv} \rangle$ – regression estimate of proportion

r^2 – coefficient of determination

s_x^2 – variance of the sample

$s_{\bar{x}}^2$ – variance of the mean

$s_{\bar{x}}$ – standard deviation of the mean

$s_{\langle\rangle}$ – standard error of the estimate

$s_{\langle\rangle}^2$ – variance of the estimate

t – Fisher's t-distribution (Student's t)

x – general random variable

$\bar{x}$ – arithmetic mean

$\Delta_{.9}$ – half-confidence interval

$100\Delta/\bar{x}$ – relative variation of the mean

$100\Delta/\langle\rangle$ – relative variation of the estimate

TABLE 8-4.— INVENTORY AND PHOTOGRAPHIC SAMPLE DATA FOR WATER PROPORTIONS

General random variable, x	Inventory estimate proportion, $\hat{p}$	Aerial photographic estimate of proportion, p	Simulated inventory, p_{inv}
$\bar{x}$	0.004	0.004	0.020
s_x^2	.000140	.000400	
$s_{\bar{x}}^2$	.000006	.000016	
$s_{\bar{x}}$	.002366	.00400	
$\Delta_{.9}$	.004049	.006844	
$100\Delta/\bar{x}$	101.2%	171.1%	
r^2		.00497	
m		-.11940	
b		.00447	
$\langle p/p_{inv} \rangle$			.02082
$s_{\langle\rangle}^2$			.00046
$s_{\langle\rangle}$			.006800
$\Delta_{.9}$			.011635
$100\Delta/\langle\rangle$			558.9%

Symbol definitions:

b – intercept

m – slope

p – aerial photographic estimate of proportion from 25 PSU's

$\hat{p}$ – simulated inventory estimate of proportion

p_{inv} – simulated inventory sample estimate from 25 PSU's

$\langle p/p_{inv} \rangle$ – regression estimate of proportion

r^2 – coefficient of determination

s_x^2 – variance of the sample

$s_{\bar{x}}^2$ – variance of the mean

$s_{\bar{x}}$ – standard deviation of the mean

$s_{\langle\rangle}$ – standard error of the estimate

$s_{\langle\rangle}^2$ – variance of the estimate

t – Fisher's t-distribution (Student's t)

x – general random variable

$\bar{x}$ – arithmetic mean

$\Delta_{.9}$ – half-confidence interval

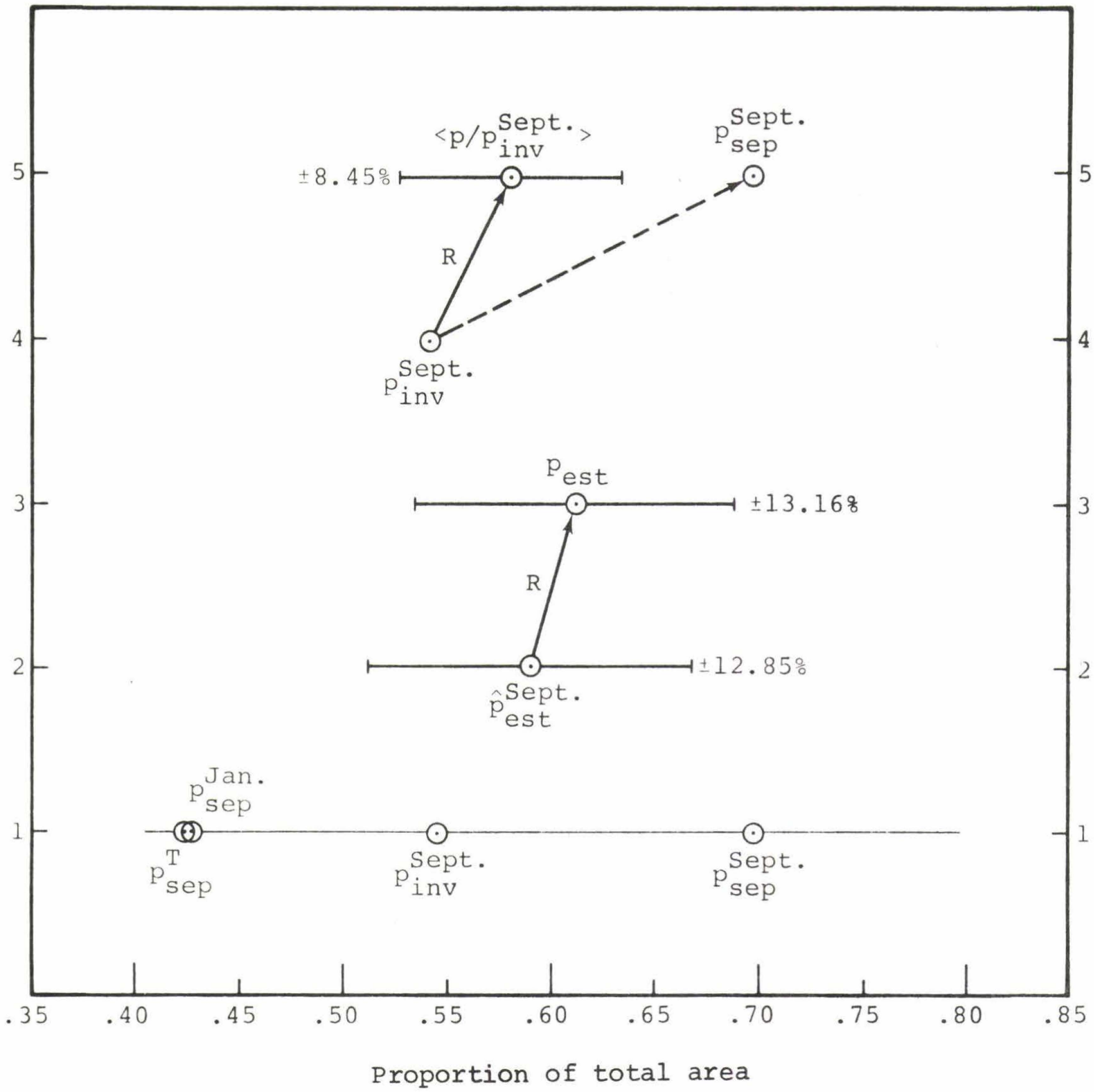
$100\Delta/\bar{x}$ – relative variation of the mean

$100\Delta/\langle\rangle$ – relative variation of the estimate

TABLE 8-5.— THE RECAPITULATION OF LEVEL I AND LEVEL II PROPORTION ESTIMATES

Type estimate	Level II			Level I		
	Softwood	Hardwood	Clear-cut	Forest[a]	Water	Other
September 1974 separability	0.707	0.062	0.057	0.769	0.021	0.152
January 1973 separability	.434	.051	.092	.485	.105	.318
Temporal separability	.426	.071	.027	.497	.026	.410
September 1974 inventory	0.544	0.082	0.016	0.626	0.020	
September inventory sample	.584	.074	.032	.658	.004	
May 1973 photographic sample	.614	.103	.0704	.716	.004	
Regression estimate	.579	.112	.058	.691	.020	

[a]Forest = softwood plus hardwood.



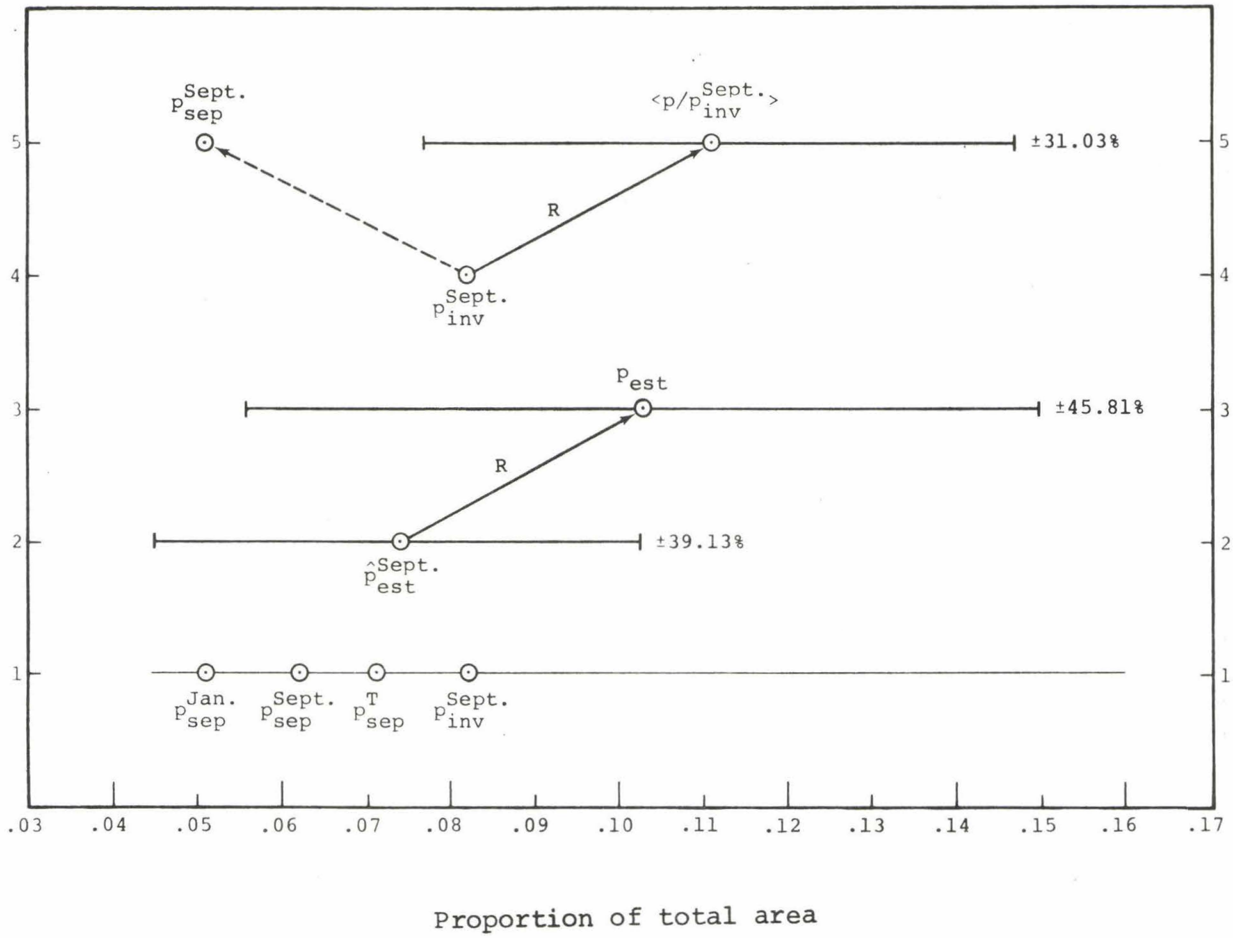
Legend:

p — proportion estimate
$\hat{p}$ — simulated inventory proportion
est — statistical estimate
inv — inventory
sep — separability
R — regression transformation
T — temporal
→ — actual transformation
--→ — expected transformation

Line number:

1 — ADP inventory and separability estimates
2 — simulated inventory estimate from 10 samples
3 — aerial photointerpretation estimate from 10 samples
4 — simulated inventory
5 — regression estimate

Figure 8-1.— Proportion estimates for softwood.



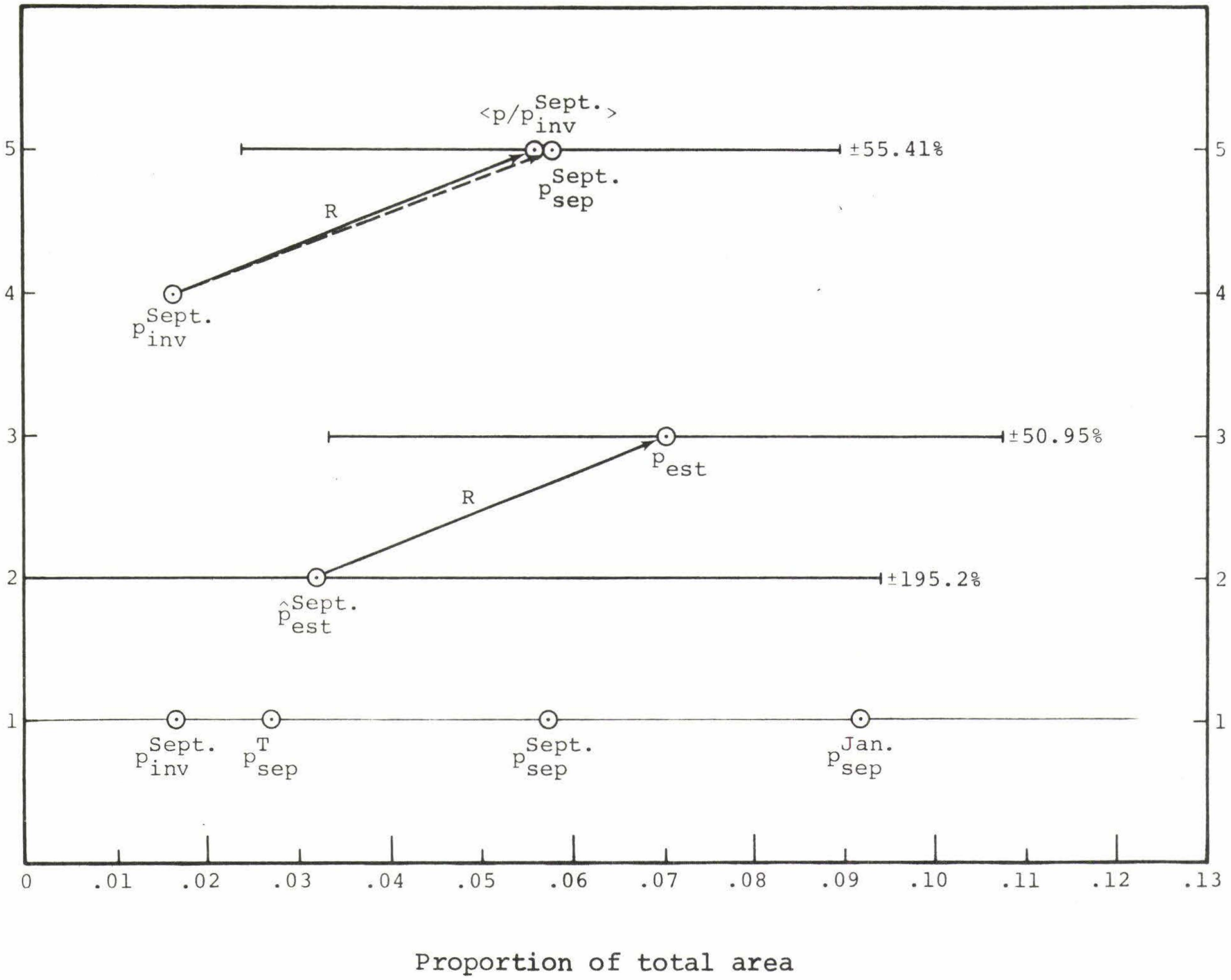
<u>Legend</u>:

p — proportion estimate
$\hat{p}$ — simulated inventory proportion
est — statistical estimate
inv — inventory
sep — separability
R — regression transformation
T — temporal
⟶ — actual transformation
- - ➝ — expected transformation

<u>Line number</u>:

1 — ADP inventory and separability estimates
2 — simulated inventory estimate from 10 samples
3 — aerial photointerpretation estimate from 10 samples
4 — simulated inventory
5 — regression estimate

Figure 8-2.— Proportion estimates for hardwood.



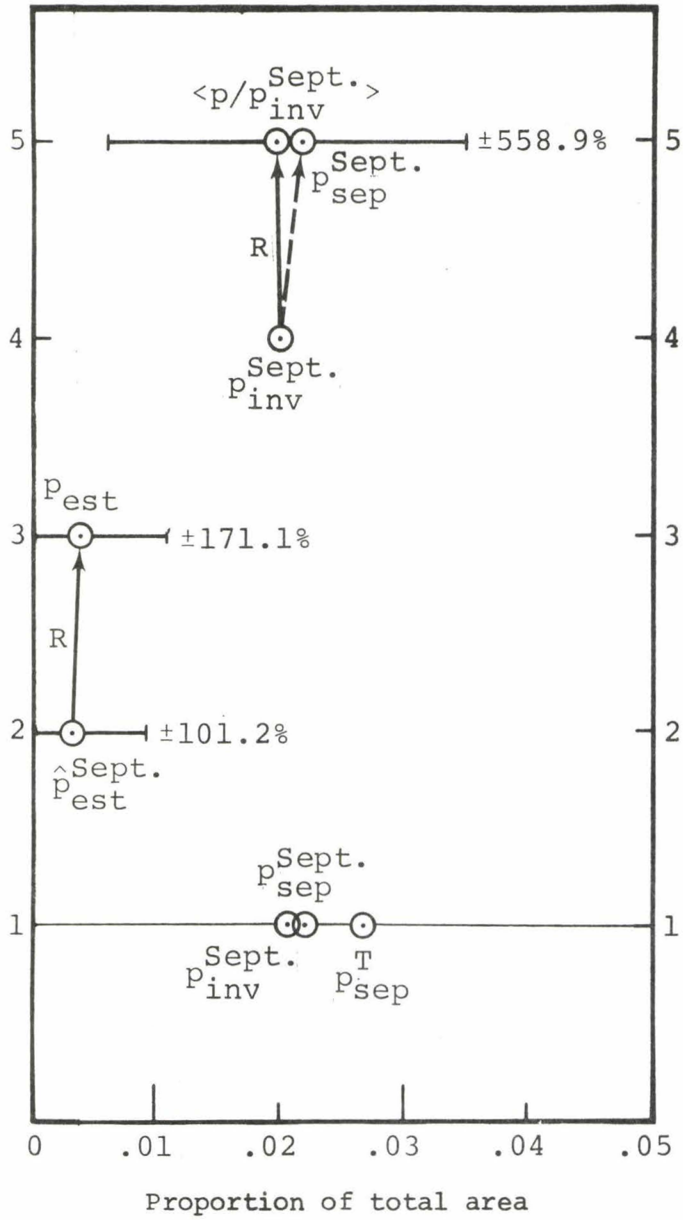
Legend:

p — proportion estimate
$\hat{p}$ — simulated inventory proportion
est — statistical estimate
inv — inventory
sep — separability
R — regression transformation
T — temporal
→ — actual transformation
--→ — expected transformation

Line number:

1 — ADP inventory and separability estimates
2 — simulated inventory estimate from 10 samples
3 — aerial photointerpretation estimate from 10 samples
4 — simulated inventory
5 — regression estimate

Figure 8-3.— Proportion estimates for clear-cut.



Legend:

p — proportion estimate
$\hat{p}$ — simulated inventory proportion
est — statistical estimate
inv — inventory
sep — separability
R — regression transformation
T — temporal
→ — actual transformation
--→ — expected transformation

Line number:

1 — ADP inventory and separability estimates
2 — simulated inventory estimate from 10 samples
3 — aerial photointerpretation estimate from 10 samples
4 — simulated inventory
5 — regression estimate

Figure 8-4.— Proportion estimates for water.

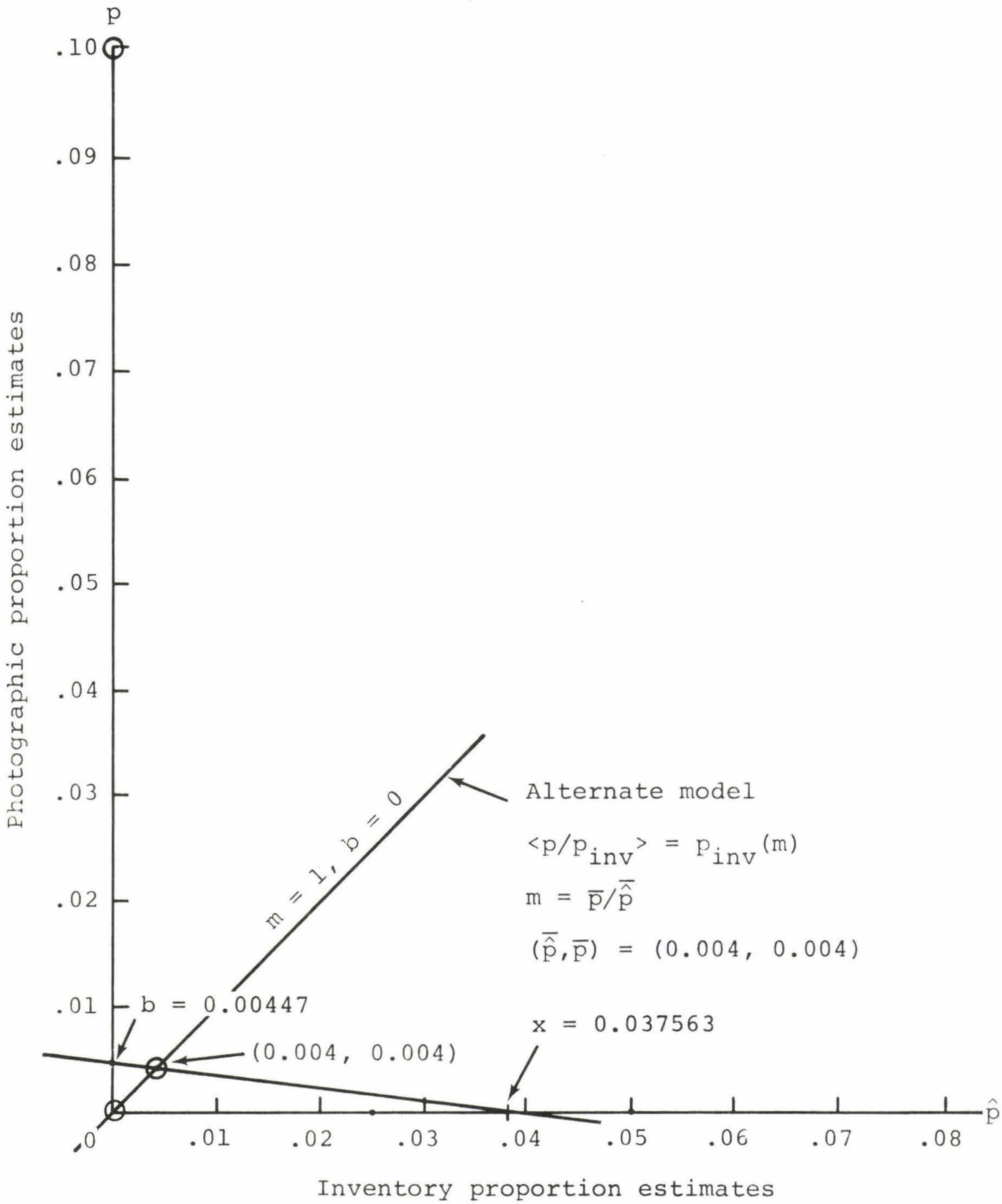


Figure 8-5.— Graph of class proportions for water.

9. CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions resulting from the analysis of Site VIII, an assessment of the technical procedures, and recommended changes for future processing systems.

9.1 CONCLUSIONS

The primary objectives of the TES and the conclusions derived from the study of Site VIII are as follows.

Objective – Investigate the feasibility of using ADP remote sensing technology to inventory forest, grassland, and water areas.

Conclusions – The results of this study indicate that the Image 100 can be used to classify Level II features from Landsat data in the Pacific Coast Conifer Ecosystem with an overall classification accuracy of 71.6 percent ±6.7 percent at the 90-percent confidence level. ADP remote sensing technology using Landsat data is feasible for those projects requiring this level of detail and accuracy.

Objective – Identify processing problems and recommend solutions pertinent to specific sites.

Conclusions – Signatures developed from 10 percent of the area and used to classify the whole scene did not adequately cover the class variability. Consequently, the proportion estimates derived from the simulated inventory were considerably different from the proportion estimates derived from the maximum information separability study. Forest Service numbers for the area are not comparable because the site does not contain a total administrative boundary such as a county or national forest.

Environmental factors affect the spectral signatures of the area and shadows cause classification problems. Changes in shadow

proportions cause problems with the temporal data; for Site VIII, the use of temporal data did not improve the separability of the classes as desired.

<u>Objective</u> – Determine the mapping accuracies of two levels of classification within the ecosystem.

<u>Conclusions</u> – The overall average Level II training field accuracy was 95.7 percent, with softwood at 99 percent for the September data set.

The overall 10-percent area training field accuracy was 96 percent, with a softwood training field accuracy of 90 percent. This evaluation of the area inventory was derived using the September data set and training fields from 10-percent of the site. The overall mapping accuracy from this inventory reflects 71.6 percent ±6.7 percent at the 90-percent confidence level.

A Level III classification using the September data showed the overall training field accuracy to be 91.7 percent. The Level III softwood 1 training field accuracy was 90 percent, softwood 2 was 85 percent, and softwood 3 was 72 percent.

<u>Objective</u> – To determine the best season or season of the year in which to perform an ADP analysis.

<u>Conclusions</u> – The amount of data was limited, restricting the analyst to January 1973 and September 1974 Landsat data only. The September data showed the better vegetation contrast.

9.2 RECOMMENDATIONS

Summarized here are suggestions for improvement in the results of the ecosystem study on Site VIII.

a. If a clustering technique (supervised or unsupervised) were used with ground-truth data used to label the clusters, a more efficient and effective classification scheme for processing may result.

b. The low Sun angle problem could be eliminated by selecting data at a time when the Sun angle is high enough to minimize shadow effects.

c. Temporal data for Site VIII or similar sites may be useful if the dates are carefully selected. An early spring and a fall date may have shown better contrast. Subsequent studies are necessary to evaluate the effectiveness of using temporal data.

d. Data-scaling operations, which are necessary to produce map output products, should be performed on the final classification data. The scaling and geometric correction of the data are not necessary for classification and can be performed more efficiently on the final output data.

From the study performed on this site and previous TES results, the following questions still require further study.

a. Does supervised or unsupervised processing provide the best results in terms of map classification accuracy?

b. How does the method used in evaluating the classification affect the results? Is one method best?

c. What data-sampling techniques can be used to estimate class proportions most accurately, as opposed to classification of each pixel in the site?

d. What is a proper basis for comparison of remote sensing classification and Forest Service data? If there is not a common base, how should the remote sensing information be presented for use by the Forest Service?

e. In evaluating the basis for a comparison of the Forest Service timber data with remote sensing classification, how should a correlation between Landsat spectral values and Forest Service ground-survey plots be made?

10. REFERENCES

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